JUSTIFICATION OF ESTIMATES FOR FISCAL YEARS 1988 AND 1989 SUBMITTED TO CONGRESS

FEBRUARY 1987

DARPA

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #61101E
USDR&E Mission Area: 530

Title: Defense Research Sciences
Budget Activity: 1. Technology Base

A. RESOURCES: ($ in Thousands)

Project Number	Title	FY 1986 Actual	FY 1987 Estimate	FY 1988 Estimate	FY 1989 Estimate	Additional to Completion	Total Estimated Costs
	TOTAL FOR PROGRAM ELEMENT	77,030	85,571	84,150	97,535	Continuing	N/A
MS-1	Materials Sciences	13,027	14,163	16,709	22,602	Continuing	N/A
ES-1	Electronic Sciences	15,671	23,960	21,346	22,529	Continuing	N/A
DRH-1	Systems Sciences	16,414	13,668	8,563	11,500	Continuing	N/A
CCS	Computer & Communications Sciences						
CCS-2	Advanced Digital Structures and Network Concepts	16,536	16,961	20,410	23,000	Continuing	N/A
CCS-3	Modernization Technology	8,383	5,589	8,922	9,604	Continuing	N/A
UDR-2	Power Source and Extra Hypervelocity Technology	2,184	1,000	700	700	Continuing	N/A
DRT-1	Armor Materials Research	2,814	8,550	5,500	5,000	Continuing	N/A
DRG-1	Geophysical Research	2,001	1,680	2,000	2,600	Continuing	N/A

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #61101E
USDR&E Mission Area: 530

Title: Defense Research Sciences
Budget Activity: 1. Technology Base

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED:

Materials Sciences. This project explores new materials, processes, structures, and device concepts, and demonstrates innovative solutions for overcoming materials-related limitations or barriers to advancements in: improved propulsion engine materials such as intermetallic compounds; metal-matrix composites; ceramics processing and ceramic matrix composites; laser countermeasure materials; synthesis of stronger and more heat resistant polymers and adhesives; solid lubrication at high temperatures; materials response at high strain rates; and radar absorbing materials and structures.

Electronic Sciences. This project explores new concepts in electronic materials, devices, and device fabrication with the goal of demonstrating their feasibility to provide new technical options for implementing future electronic systems. Strong emphasis is placed on pursuit of unique combinations of performance, survivability, and cost required of DoD systems. Technologies pursued include: digital integrated circuits, acoustic charge transfer (ACT) devices, millimeter wave and optoelectronic circuits of submicron feature size utilizing either compound semiconductors or silicon; electro-optical (especially infrared) sensors; optical computing and processing materials and devices and monomolecular electronically active polymer films.

Systems Sciences. The objective of this program is to carry out highly innovative, small scale, interdisciplinary systems research leading to improved effectiveness of Armed Forces personnel in accomplishing their mission responsibilities. Research areas include: systems for land based travel; systems for autonomous navigation; development of the advanced biochemical technology base for broad-based defense and intelligence applications; and development of innovative mathematical methodologies for solving critical scientific and engineering problems in DoD, such as: improved design capabilities for military vehicles; characterization of turbulent fluid flow; improved combustion efficiencies; and the stability of spacecraft with flexible appendages.

Computer and Communications Sciences. This program supports basic research in information processing and computer communication technology to provide a technological base for the development of future intelligent, network-based, military systems and for improved productivity through automation. The focus is on basic concept development, and includes the development and exploitation of advanced concepts in robotic software and automation technology design systems, advanced system network concepts, and Very Large Scale Integration (VLSI) architecture and design. User interface technology is being developed to offer more effective and efficient access to computers and tactical weapon systems. A modernization technology effort is providing experimental computer resources to improve research productivity at the forefront of computer science, and developing advanced VLSI design systems, advanced control and manipulation techniques and increased defense manufacturing productivity through the use of advanced automation techniques. Experimental computer resources are being provided to major universities in order to upgrade their resources to adequately support their DoD research. This portion of the program will continue through FY 1988.

Program Element: #61101E
USDR&E Mission Area: 530

Title: Defense Research Sciences
Budget Activity: 1. Technology Base

Armor Materials Research: This project provides basic research to support all aspects of the Armor Program in Program Element No. 62702E. Included areas of effort are: low-cost processing of ballistic ceramics; development of new alloys and processing methods for tungsten and depleted uranium; development of light-weight, high-strength cermets, and improvements in modelling high rate deformation phenomena; computational penetration mechanics; dynamic materials properties measurement and constituitive modelling; advanced measurement and diagnostic techniques for ballistic evaluation; fundamental investigations of the physical mechanisms of armor penetration; development of advanced materials and processes for armor and munitions; and studies of the thermo-chemical processes in explosive detonation and deflagration/detonation transitions. The Los Alamos National Laboratory, as the Independent Management Activity (IMA) in the Armor/Anti-Armor Program, will coordinate, direct, and participate in this research project. This basic research leads directly to advances in the performance of munitions and armor systems and will be coupled immediately to the industrial development teams by the IMA.

Geophysical Research: This program is aimed at conducting basic research and development to enhance U.S. capabilities for monitoring nuclear explosion events. Consideration of a nuclear test ban requires detailed technical information on explosion driven seismic sources, high frequency, seismic wave propagation, and procedures to differentiate explosion signals from those occurring naturally (earthquakes). A nuclear test ban would require the highest possible level of monitoring capability to verify that the Soviets were or were not employing evasive techniques and to reduce the number of possible false claims of cheating. This capability rests on a foundation of basic seismological geophysics which is extended and maintained through DARPA funding of university research. This basic research also leads directly to improvements in the U.S. ability to estimate the yields of Soviet underground explosions and thus to evaluate their weapons program and to verify compliance or non-compliance with the Threshold Test Ban Treaty.

C. COMPARISON WITH FY 1987 DESCRIPTIVE SUMMARY:

Materials Sciences. The $6.2 million reduction in FY 1987 and $8 million in FY 1988 will severely limit follow-on and new projects in ceramic processing and ceramic composites, metal matrix composites, and high temperature polymers. The rapid solidification alloy research will be phased out more quickly than planned, and growth of the radar absorbing materials research will decelerate.

Electronic Sciences. Although the total funding for this area has suffered only a minor decrease, the totals are net figures resulting from severe cuts in the areas of digital integrated circuit research, optoelectronic circuit research and solid state millimeter wave device research and a large increase in the Acoustic Charge Transfer (ACT) Program. Starting in FY 1988 the mercury-cadmium-telluride program will be transitioned into the 62301E Program Element (Project ST-12).

System Sciences. The $13 million reduction for FY 1988 compared to the figure in last year's Descriptive Summary, is for the most part due to the transition of the technology for the development of command and control support systems to Program Element 62301E.

Program Element: #61101E
USDR&E Mission Area: 530

Title: Defense Research Sciences
Budget Activity: 1. Technology Base

Computer and Communications Sciences. Reductions for the Advanced Digital Structures and Network Concepts project reflect cutback in planned funding for enhanced capability modifications for the adaptive network program in response to general budget reduction requirements. Reduction for the Modernization Technology project reflect changes to planned computer resources and software support expenditures as a result of general budget reduction requirements.

Armor Materials Research: This project grew to approximately $8.5 million in FY 1987 as the Independent Management Activity in the Armor/Anti-Armor Program began its research program. The level of effort will decrease to approximately $6.5 million in FY 1988 and then level out at approximately $5 million in subsequent years. The somewhat higher funding in FY 1987 was required to develop basic tools to evaluate ballistic events and the subsequent level of effort of approximately $5 million per year is required to ensure continued technological advances in the Armor/Anti-Armor Program.

Geophysical Sciences: The FY 1987 funding for this area is reduced from that anticipated in the previous year's Descriptive Summary to take into account budgetary reductions placed on Defense Agencies and to accomodate other programs within Program Element 61101E.

D. OTHER APPROPRIATION FUNDS: Not Applicable.

E. RELATED ACTIVITIES:

Materials Sciences. DARPA programs in metal-matrix composites, rapid solidification technology, solid lubrication, advanced ceramics, and high temperature polymers and adhesives are coordinated with other service efforts and other agencies through a number of committees and interagency groups, including: National Science Foundation; Interagency Materials Coordinating Committee; Interagency Working Group on Ceramics for Heat Engines; Interagency Committees on Rapid Solidification and Metal-Matrix Composites; and Tri-Service Laser Hardened Materials Working Group. The developments of radar absorbing materials and structures is directly connected to low-observable activities in the three Services.

Electronic Sciences: The Services have programs developing specific infrared sensor devices. The DARPA program is focused on demonstration of new "silicon-like" materials growth, processing, and characterization for infrared sensor arrays, principally using mercury-cadmium-telluride. The DARPA programs in optical processing complement the algorithm and architecture programs of the Air Force Office of Scientific Research with efforts in material and device development. The research effort in submicron device and materials technology complements the DoD Very High Speed Integrated Circuits (VHSIC) program by addressing long range problems in design and fabrication of materials and devices that operate at or very near their physical limits and are fabricated in high vacuum via in-situ combinations of beam processing steps. A number of efforts are funded cooperatively with the Air Force Office of Scientific Research, Office of Naval Research, and Army Research Office, the Air Force Wright Aeronautical Laboratories Materials Division, and the Naval Ocean Systems Command.

Cooperative research efforts with the National Science Foundation at universities concerning use of synchrotron radiation, submicron structures, and crystal growth research are in progress.

Systems Sciences: These efforts are coordinated with the Defense Mapping Agency; the U.S. Army Armor Center, Department of the Army; the Air Force Rome Air Development Center; the Air Force Wright Aeronautical Laboratories, and the U.S. Army Engineering Topographic Laboratories. Chemical ultrasensor research is closely coordinated with the Army and complements the latter's efforts by focussing on long range materials processing, integration, and device design concept issues. Other efforts in this area are coordinated with a large number of other organizations in all three services.

Computer and Communications Sciences: The multi-Service effort on Very High Speed Integrated Circuits (VHSIC) is focused on very high speed technology and complements the DARPA program which is addressing architecture and design concepts for very large scale systems. The National Science Foundation (NSF) has a basic research program in submicron structures which is being coordinated with the DARPA program. DARPA maintains close technical liaison with the Defense Communications Agency on new computer communications protocols and advanced network concepts. NSF and the Military Services are also providing sorely needed computer equipment to research institutions and some industry vendors are offering sizeable discounts to universities. NSF, the National Aeronautics and Space Administration, the Office of Naval Research, and the Army Research Office also support research in robotics. The Defense NATO Network Program Office carries out new team efforts on network architecture. Coordination with users and other sponsors of related research is maintained through joint programs, workshops, conferences, meetings between program managers, site visits, choice of contracting agent, and published research.

Armor Materials Research: This project is coordinated with the Army and the Marine Corps by joint efforts and through oversight by an executive Steering Committee that includes members of the Army and the Marine Corps.

Geophysical Sciences: Complementary research is conducted by the national laboratories of the Department of Energy. The topics of seismic wave propagation and of earthquake source mechanisms are also of fundamental scientific interest and are of importance for earthquake hazard reduction. For these reasons research on these topics is also supported by the National Science Foundation and by the Nuclear Regulatory Commission. Coordination of DARPA's effort with these agencies to avoid duplication is accomplished by formal meetings between agencies and by the National Academy of Sciences Committees on Geophysics and Seismology.

F. WORK PERFORMED BY:

Materials Sciences: Effort is distributed among performers as follows: 55% industry, 21% universities, 13% in-house government laboratories and 11% federally funded research and development centers. The major performers include: Battelle Columbus Laboratories, Columbus, Ohio; GTE Sylvania, Towanda, Pennsylvania; Dow Chemical Company, Midland, Michigan;

Rockwell Science Center, Thousand Oaks, California; BDM Corporation, McLean, Virginia; Lanxide Corporation, Newark, Delaware; General Electric Co., Evendale, Ohio; Babcock and Wilcox, Lynchburg, Virginia; Hughes Aircraft Company, El Segundo, California; University of Michigan, Ann Arbor, Michigan; University of Massachusetts, Amherst, Massachusetts; Massachusetts Institute of Technology, Cambridge, Massachusetts; Michigan State University, East Lansing, Michigan; University of California at Santa Barbara, Santa Barbara, California; and Virginia Polytechnic Institute, Blacksburg, Virginia. In-house laboratory efforts are performed at the Naval Research Laboratory, Washington, D.C.; Air Force Wright Aeronautical Laboratories/Materials Laboratory, Dayton, Ohio; the National Bureau of Standards, Gaithersburg, Maryland; Lawrence Livermore National Laboratory, Livermore, California; and Los Alamos National Laboratory, Los Alamos, New Mexico.

Electronic Sciences: Approximately 33% of this work is performed by industry, 66% by universities and 1% by government laboratories. The top industrial performers include: Rockwell International Science Center, Thousand Oaks, California; Texas Instruments, Dallas, Texas; and Celanese Research Center, Summit, New Jersey. The top university performers are: Stanford University, Palo Alto, California; Massachusetts Institute of Technology, Cambridge, Massachusetts; and California Institute of Technology, Pasadena, California. In-house performers are the Naval Research Laboratory, Washington, D.C., and Naval Ocean Systems Center, San Diego, California.

Systems Sciences: 50% universities, 33% industry, 17% in-house. Major performers include: Boston University, Boston, Massachusetts; Michigan State University, East Lansing, Michigan; University of Florida, Gainesville, Florida; Harvard University, Cambridge, Massachusetts; University of California, San Diego, San Francisco, and Santa Barbara, California; and the California Institute of Technology, Pasadena, California. The Naval Research Laboratory (NRL) performs much of the in-house work.

Computer and Communications Sciences: 81% university, 11% industry, and 8% are in-house. The major performers are Bolt, Beranek, and Newman, Cambridge, Massachusetts; California Institute of Technology, Pasadena, California; Carnegie-Mellon University, Pittsburgh, Pennsylvania; Columbia University, New York City, New York; Massachusetts Institute of Technology, Cambridge, Massachusetts: MIT Lincoln Laboratory, Lexington, Massachusetts; Stanford University, Palo Alto, California; University of California, Berkeley, California; University of California, Los Angeles, California; University of Maryland, College Park, Maryland; University of Rochester, Rochester, New York; University of Southern California, Information Sciences Institute, Marina Del Rey, California; and Yale University, New Haven, Connecticut.

Armor Materials Research: Approximately 90% of this work is performed by the Los Alamos National Laboratory, Los Alamos, New Mexico. Of the remaining, 6% is performed by industry and 4% by universities. Top performers include: GTE Products, Towanda, Pennsylvania; SRI International, Menlo Park, California; the University of Washington, Seattle, Washington; the University of Texas, Austin, Texas; Trans-Science Corporation, San Diego, California; and Honeywell, Inc., Minneapolis, Minnesota.

Geophysical Sciences: Ninety-two percent of this work is performed by universities, 4% by foreign firms and 4% by government in-house. Top performers include: University of California, Berkeley, California; California Institute of Technology, Pasadena, California; Massachusetts Institute of Technology, Cambridge, Massachusetts; Pennsylvania State University, University Park, Pennsylvania; St. Louis University, St. Louis, Missouri; University of Southern California, Los Angeles, California; and the U.S. Geological Survey, Reston, Virginia.

G. PROJECTS LESS THAN $7 MILLION IN FY 1988 - 1989:

Armor Materials Research: Project accomplishments in FY 1986 included: development of processing techniques for cermets that demonstrated a light-weight, high-strength material with greatly improved ballistic resistance; completion of the development of ultra-high carbon steel (a low alloy steel with extreme hardness); significant advances in the processing of liquid-phase-sintered tunsten-nickel-iron alloys; and continued progress in advanced underwater warhead concepts for anti-submarine warfare. Program planning and research task definitions were initiated at Los Alamos National Laboratory. In FY 1987, work on underwater warhead technology is being transferred to the Navy. Work is continuing on development of new materials and processing to support the Armor/Anti-Armor Program (see Project Number TT-04 under Program Element No. 62702E), and a new thrust is being initiated to develop improved tungsten for kinetic energy penetrators by pulse-power sintering with Homopolar Generators. Research in computational penetration mechanics, advanced materials, basic mechanisms of armor defeat by advanced munitions, and diagnosis of ballistic events is being initiated at Los Alamos. In FY 1988, research on advanced materials will be coordinated with Los Alamos National Laboratory and with the Armor Team Leaders established in the Armor/Anti-Armor Program (see Project No. TT-04 under Program Element No. 62702E). Beyond FY 1988, Los Alamos will provide a research base and coordination of research efforts for the Armor/Anti-Armor Program. This will assure rapid transfer of new technology to the industrial teams developing advanced armor and munitions in the Armor/Anti-Armor Program.

Geophysical Sciences: In FY 1986 a large scale seismic tomographic analysis of earth structure continued to determine detailed information on heterogeneous variations of seismic velocity within the earth. Research to use this information should lead to more accurate locations of seismic events in a monitoring context. The improved earth structure should also lead to more accurate yield estimates by means of magnitude from long-period Rayleigh waves. By use of improved instrumentation it was found that high-frequency noise levels at quiet sites are much lower than was thought heretofore. This implied that decoupled explosions could perhaps be detected at lower yields than previously thought possible. In FY 1987, emphasis is being placed on the analysis and evaluation of data from the regional array in Norway to further elaborate the propagation of high frequency signals at regional distances. Methods to utilize additional information in the seismic signals from explosions for independent estimates of yield have been developed, and methods have been developed to isolate explosion signals from triggered earthquakes. This has important implications for improving the verifiabiity of a Threshold Test Ban Treaty and for the methods which should be used to estimate precise yields. In FY 1986 the tomographic research was completed in order to better outline the 3-dimensional structure of the earth and to gain the location and yield-estimation

benefits discussed above. Research is being funded to outline the geographical distribution of low noise sites and to understand the source of the existing noise. These tasks should help predict the locations of low noise sites. Patterns in body waves are being studied to understand the cause of the patterns: propagation through varying earth structure or release of tectonic strain. Analysis and evaluation of the tectonic strain release which affects surface wave yield estimates is underway using long-period body waves. This research has given additional confidence in propagation bias estimates between Soviet and U.S. test sites. Close-in monitoring of underground tests at the Nevada Test Site and laboratory modelling experiments are helping to resolve issues on non-linear propagation under moderate strain. Earthquakes are being monitored at close distances to see if their source spectra have significant differences from those of explosions. Theories of complex earthquakes are being developed. Such earthquakes may have source spectra similar to those of explosions. Theoretical approaches to 3-dimensional scattering and propagation are being developed to compare to model studies and to finite difference calculations. These studies are of importance in developing regional discriminants which are the only discriminants which may be used for weak decoupled explosions.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: MS-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: Materials Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The objectives are to explore new materials concepts, and seek solutions to problems which require specially tailored materials such as intermetallic compounds, metal matrix and ceramic matrix composites, high temperature polymers and adhesives, easily processed low-cost ceramics, materials resistant to laser irradiation, solid lubricants for ceramics at high temperatures, polymers, and engineered materials with enhanced nonlinear optical properties. The full exploitation of high temperature intermetallics and ceramic matrix composites will make possible a two-fold increase in thrust-to-weight limits for advanced gas turbines, advanced cruise missiles and tactical aircraft. New titanium alloys emerging from this technology will surpass heavier superalloys for achieving weight, cost, and fuel reductions in advanced aircraft and missiles. Metal-matrix composite research is addressing new fabrication technologies for achieving high stiffness and high strength structural alloys for use at elevated temperatures and new methods combining the advantages of rapid solidification metallurgy with metal matrix composite technology in titanium alloys and advanced intermetallic matrix composites. New techniques in polymer synthesis and polymer composite and adhesive processing, including electromagnetic processing, will lead to lightweight structures designed for longer life at higher temperature. Potential DoD applications include structural members and coatings for high performance aircraft and the National Aerospace Plane, and composite structures for space. Novel ceramic processing approaches, including explosive compaction and chemical synthesis techniques to produce low cost, reliable ceramics and ceramic matrix composites for structural and optical applications, are being evaluated. A program to harden materials against shock waves induced by pulsed lasers will develop new composites to mitigate the effects of shocks by energy dissipation via microstructural control. Research in the fundamentals of solid lubrication of ceramics in severe environments is providing options for lubrication of high temperature engines and satellites where conventional liquid lubrication approaches cannot be employed. Processing routes for polymers and ceramics using electromagnetic energy (e.g. microwaves) are being investigated. The development of a new class of polymeric composite "molecular composites" is being undertaken, which will provide high modulus, strength and temperature and chemical stability at temperatures up to of 450°C. New composite materials with superior mechanical properties will be adapted to the requirements of low radar signature to provide a new class of structural

Project: MS-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: Materials Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

composites with high microwave attenuation. Efforts are also examining the behavior of materials subjected to high strain rates such as in ballistic impact. This research includes modelling via computer hydrocodes as well as experiments aimed at assessing the mechanical response of metals and ceramics to very high rates of deformation and fracture.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: Significant advances were made in materials research efforts covering a wide range of materials systems including metals, ceramics, polymers, and composites. Significant advances this year have been made in ceramics research. The research on explosive compaction of ceramic powders was completed. This technique was shown to be very powerful for the forming of compositions that would be impossible using conventional ceramic processing. This may be especially important as a low cost approach to producing high performance ceramic armor. The technology has been transitioned to DARPA's Armor/Anti-Armor Program, where explosive compaction of ceramic powders to form plates will yield materials which will be subjected to ballistic evaluation. In addition, a major breakthrough has been made in Lanxide technology. Research on this proprietary process which can make ceramic and ceramic composites with unique compositions and to net shape showed the process could be used to make ceramic composites having a variety of compositions. It is possible to produce a variety of monolithic ceramics and fiber reinforced ceramic composites by this process. New basic research on the micromechanics of brittle composites will develop theories to predict performance.

In the polymer alloying research, a strong, tough, high temperature (up to 450°C) polymer blend was demonstrated, and is being evaluated for potential application in the Advanced Tactical Fighter (ATF) program and in engine components. Rapid Solidification Plasma Deposition (RSPD), a process to directly deposit structures with rapidly solidified microstructures, was successfully applied to fabrication of titanium aluminide composites for hypersonic aircraft. In the program on ultra-fine alloys and composites, new strong, tough, weldable aluminum alloys were developed which offer significant weight reduction in future ship structure concepts, potentially providing naval vehicles with much greater speed and range, larger payload, and greater firepower.

Project: MS-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: Materials Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

An initial evaluation of fabricating composite structures for radar protection in extreme environments has shown that excellent performance can be achieved.

Studies of the effects of high intensity pulsed laser radiation on composite materials have shown these materials may be susceptible to failure induced by shock wave fracturing the load-carrying fibers. A prior effort to develop Continuous Wave (CW)-laser hardened materials, just completed, demonstrated new classes of carbon-carbon composites with extraordinarily high resistance to laser penetration. The results of this program have been transitioned to the Strategic Defense Initiative Organization (SDIO).

During FY 1986, the effort on rapid solidification of depleted uranium was carried on in program element 62702E (Project TT-04) to further develop powders and consolidated projectiles with improved properties for kinetic energy penetrators.

A comprehensive state-of-the-art re ew by leading experts in the field of material modelling and large-scale computer code development was conducted to assist in penetration mechanics in Armor/Anti-Armor. Results were used to guide future programs designed to predict the behavior of materials under very high strain rates as required, for example, in modern armor systems.

b. FY 1987 Program: The strong effort in processing ceramics composites continues. The exploratory phase of the Lanxide program is being completed with a demonstration of: an understanding of the process mechanisms; near net shape forming of ceramic bodies; and the ability to make composites for a variety of DoD applications. The effort to form single crystal sapphire infrared (IR) domes to net shape has shown it is possible to grow near net shape one inch diameter crystals. Optical and physical properties of the crystals formed via this process are being evaluated. The project to demonstrate the use of supercritical fluids in the densification of ceramic and carbon-carbon composites has identified polymer compositions amenable to infiltration into the composite structure. A project on fracture of brittle matrix (ceramic) composites is now modelling the behavior of these materials during the fracture process.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: MS-1
Program Element: *61101E
USDR&E Mission Area: 530

Title: Materials Scien
Title: Defense Resear Sciences
Budget Activity: 1. T nology Base

The theoretical and experimental approaches to the blending of polymers is continuing, and a major new effort to apply the polybenzinidizole/polyimide high temperature blend developed in FY 1986 to advanced air frame and engine components is being initiated. Promising new liquid crystalline polymer combinations are being blended based on theoretical predictions of optimum processing conditions, and the physical properties of the resulting polymer systems are being measured. A program begun in FY 1986 is aimed at establishing novel chemical, mechanical, and evaluation approaches for improved high temperature polymeric adhesives. The goal of this effort is synthesis of adhesives capable of withstanding up to 450°C with extended service life. New synthetic polymer approaches have shown initial success. Another effort begun in FY 1986 is examining the use of electromagnetic energy (e.g. microwaves) for the processing or synthesis of unique polymers. The effort in molecular composites for new classes of high temperature, high strength polymers is continuing with the goal of investigating scale-up of processing of specific chemistries and the possibility of reinforcement of these polymers by rigid rod molecular structures of identical chemistry.

The effort on weldable marine structural alloys focuses on weld zone morphology control and improving alloying concepts to make more rapidly solidified aluminum alloys weldable, especially the improved modulus aluminum-lithium alloys. This effort will be completed in FY 1987 and transitioned to the Navy.

A program initiated in FY 1986 is being continued to evaluate advanced intermetallic alloys for use in new metal matrix composites which have both high specific strength and modulus, and are stable at temperatures up to 1800°C for application in extremely high velocity air vehicle structures. The first phase of this effort is focussed on metal alloying concepts and processing science for high strength combined with increased ductility and creep resistance. Recent advances, especially with titanium aluminide matrices, have indicated directions to dramatically improve the ductility of these inherently brittle alloys in order that they may be formed into useful shapes.

The effort to develop improved mathematical constitutive models for use in large-scale computer simulation programs is being applied to Armor/Anti-Armor research. The work in FY 1987 has been

curtailed due to funding limitations. Future work concentrating on studies of materials behavior at high strain rates and the micromechanics of deformation will be transferred to the DARPA Armor/Anti-Armor Program.

A program to develop radar absorbing materials for extreme environments is being initiated. The intent is to provide extended countermeasure capability for a variety of aerospace systems.

The shock hardened materials development program is examining shock mitigation in materials by fundamental experiments and correlated theory. Pulsed laser initiated shock waves is being studied by means of special diagnostics which afford an instantaneous view of the material during shock passage. Theoretical development is attempting to obtain a microstructural description of shock passage and attentuation. Research is being aimed at developing experimental data and theoretical modelling which will provide the basis for selection of composite materials for aerospace structures which are resistant to irradiation by pulsed lasers.

c. FY 1988 Planned Program and Basis for FY 1986 Request: The efforts in ceramics research will continue to explore novel routes for the processing of ceramics and ceramic composites. Lanxide technology will be expanded to include a more in-depth analysis of the basic mechanisms of this unique process. The use of supercritical fluids in the processing of ceramic and carbon-carbon composites will be completed. The modelling effort to understand the fracture behavior of ceramic composites has been expanded with experimental work on ceramic composite samples produced in other DARPA and DoD programs.

The program to examine the fundamentals of solid lubrication of ceramics will continue. The first priority of this program is to establish the fundamental mechanisms of the lubrication process. New testing and surface analytical techniques will be developed to examine tribological behavior.

In the high temperature polymers and adhesives program, the effort on polymer alloying via blending for co-polymeric systems has established the basis for processing polymers and composites which have thermal stability at 400-500°C, and new polymer systems will be developed. The processing routes will be

transitioned to service programs for improved polymers for missile, air and land warfare structures. New adhesive systems with order-of-magnitude lifetime improvement in severe environments will be formulated for bonding of titanium and advanced composites.

The technology for future manufacture of molecular composites based on the efforts in the high temperature polymers program will be established via a joint DARPA/Air Force activity. This effort will serve as the basis for new technology base programs in the Services for improved polymeric composites which have stability in applications above 400°C.

Metal matrix composite research will be emphasizing refractory metal and intermetallic alloys for the matrix phase. Studies of the deformation and fracture mechanisms of these materials will be developing a rationale for design with these low ductility metal matrix composites. In the effort on electromagnetic processing of materials, methods for processing both organic polyimide composites and structural ceramics and ceramic composites will be studied. These materials have the potential for high performance capability without the performance penalties associated with traditional processing routes for these materials.

In examining shock propagation and mitigation in composite structures, improved diagnostics will provide a practical basis to examine microstructural models to determine their validity. The effort to develop improved constitutive models for use in large scale computer simulation will continue with model development and validation work aimed at understanding the response of materials to high rates of deformation.

d. FY 1989 Planned Program and Basis for FY 1989 Request: Selected studies on high temperature (e.g. titanium-based) metal matrix composites will be undertaken. Research on ceramic processing will identify low cost processing techiques to produce improved ceramic and ceramic composites for gas turbines, armor, and radar absorbing structures. New chemical synthesis routes will be explored to fabricate tougher, stronger and stiffer high temperature polymers. Improved radar absorbing

structures will be developed, and materials will be synthesized which have great resistance to pulsed laser irradiation.

e. Program to Completion: The feasibility of novel concepts for ceramic and ceramic composite fabrication will be determined and those that are promising will be transitioned to exploratory development programs. Advanced ceramic and solid lubrication formulations will be evaluated and transitioned to development programs for bearings, seals, etc.. Research on high temperature polymers, high temperature adhesives, and electromagnetic energy processing will continue, with emphasis on developing fundamental knowledge leading to improved materials for military systems. Selected studies on novel metal-matrix composites will continue with a goal of producing high temperature, strong, tough, lightweight structural components for airframes, missiles and space applications.

f. Milestones: The FY 1986 milestones reported in the FY 1987 Descriptive Summary have been completed on schedule.

Last Year's Reported Plan	Current Plan	Milestones
Early FY 1987	Early FY 1987	Demonstration of applicability of constitutive mechanics models to predict behavior of materials under high rates of loading.
--	Early FY 1987	Provide analytical basis for designing radar absorbing structures under extreme environments.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: MS-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: Materials Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestones
Late FY 1987	Late FY 1987	Demonstrate processing capability for molecular composites with optimum mechanical properties.
Late FY 1987	Late FY 1987	Determination of energy budget for pulsed laser effects on composite material.
Early FY 1988	Early FY 1988	A detailed assessment of the advantage of Lanxide ceramic technology in a variety of DoD applications will be completed.
--	Early FY 1988	Fundamental micromechanics principles for predicting the performance of brittle matrix composites will be developed.
--	Late FY 1988	Demonstrate coupon-sized radar absorbing composite structure which can sustain extreme environments.
Late FY 1988	Late FY 1988	Approaches for the solid lubrication of ceramics at both high (850°C) and low (-50°C) temperature will be established.
--	Early FY 1989	Determine materials basis for counteracting the in-band agile laser threat to sensors and eyes.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: MS-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: Materials Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestones
--	Early FY 1989	New niobium based intermetallics will be developed for high temperature turbine applications up to 1540°C.

g. Explanation of Milestones Changes: None.

I. TEST AND EVALUATION DATA: Not Applicable.

J. COOPERATIVE AGREEMENTS: Not Applicable.

Project: #ES-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: Electronic Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The objective of this project is to explore and demonstrate device, material, and material processing concepts which will provide: (1) new technical options for implementation of future electronic and optical systems and functions for information transmission, gathering and processing; and (2) substantial increases in performance, survivability, reliability, and availability of electronic components and monolithic, high functional throughput circuits at reduced cost per function. Specific areas of electronic and optical materials device and manufacturing research include revolutionary new approaches to produce large area infrared sensor materials and devices for strategic and tactical systems; innovative processes, device design concepts, electronic and optically active polymeric supramolecular thin film structures; photorefractive materials and device development for achieving spatial light modulators; nonlinear optical effects for analog and digital optical computing; and signal processors using acoustic charge transport (ACT) technology. In the FY 1987 Descriptive Summary ACT was reported under program element 62301E (project ST-07). This transfer to Project ES-01 recognizes the truly basic research nature of this device technology.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: Controlled substitutional doping of high quality thin films of cadmium telluride (CT), both n- and p-type, has been achieved through laser illumination of the underlying substrate during molecular beam epitaxial growth. One important outcome of this breakthrough is the possibility of integrating CT signal processing circuitry and mercury cadmium telluride (MCT) detectors on the same substrate. Device quality epilayers of mercury cadmium telluride (MCT), mercury manganese telluride (MMT), mercury zinc telluride (MZT), and cadmium zinc telluride (CZT), have been reproducibly grown by molecular beam epitaxy (MBE) through stoichiometric adjustment. Substitutional doping has been routinely achieved in n-type MBE-grown MCT. Heterojunction MCT structures have been grown in situ by MBE. The relationship between bandgap and layer thickness in MT-CT superlattices has been established, and good agreement with theory has been found. As predicted, for longer wavelengths

(greater than 10 microns), bandgap control is easier in MT-CT superlattice structures than in the equivalent MCT alloy.

Continuous improvements in metal organic chemical vapor deposition (MOCVD) growth and in the processing of Permeable Base Transistors (PBT's) have led to results surpassing those achieved with any other transistor; including power-added efficiency of 66% with 15 decibels (dB) of gain at 1.3 gigahertz (GHz) and 41% with 7 (dB) of gain at 20 gigahertz (GHz), a maximum stable gain of 21.3 dB at 18 GHz, and a room temperature switching speed of 3.2 picoseconds.

A 128 X 128 electronically-addressed two-dimensional spatial light modulator operating at one thousand frames per second was successfully prototyped. The major application of such a modulator is to convert one-dimensional electrical signals (e.g., image scans and radar returns) into two-dimensional optical signals for parallel optical processing (e.g., operations such as correlation, matched filtering, fast fourier transforming, and visual displays). University and industry researchers successsfully collaborated to incorporate nonlinear optical molecules into the pores of sol/gel glass. This produced a material with the environmental stability of glass, but exhibiting a large nonlinear optical behavior which is necessary to produce all-optical switching devices.

A new process for depositing thin films, called Limited Reaction Processing (LRP) was discovered. This new process could be as much as 10 times cheaper than the currently used process of Molecular Beam Epitaxy (MBE) and will be much faster. The results have been so outstanding that technology transfer to the electronics industry is expected to occur soon.

A new state-of-the-art optically-addressed two-dimensional (2D) spatial light modulator, called the Microchannel Spatial Light Modulator (MSLM), was demonstrated. The MSLM converts weak, incoherent, visible-light images into high-indensity, coherent, laser light images for input to optical computers.

Researchers at Stanford University grew and characterized very high-purity gallium arsenide (GaAs) and aluminum gallium arsenide (AlGaAs) layers by molecular-beam epitaxy (MBE), achieving record high

electron mobilities. These structures are the basis for some of the fastest electronic devices currently at the research stage.

Acoustic Charge Transfer (ACT) technology matured greatly during this first year of significant funding. Device fabrication processes were proven, material suppliers and material evaluation procedures were qualified and experimental devices were consistently produced. Significant progress on the difficult problem of interface circuit design was made and high performance ACT test fixtures were fabricated. Small joint efforts were begun with the Air Force, Navy and CIA to develop single devices capable of near term exploitation.

b. FY 1987 Program: Materials and device efforts directed towards achieving millimeter wave, three terminal devices are continuing. Emphasis is placed on utilization of velocity overshoot to achieve the carrier velocities required to realize such devices. Specific device structures for which materials and processing research is underway include the Permeable Base Transistor (PBT), the Heterojunction Bipolar Transistor (HJBT) and tunneling structures. Realistic electronic structure and device modelling efforts continue in order to provide guidance for the experimental materials and device research. Electrooptical measurement techniques with subpicosecond resolution are being developed for investigating the physics of ultra high speed structures and as a potential replacement for slower, cumbersome electrical approaches.

Research on growth and processing of large area mercury cadmium telluride (MCT) and other II-VI infrared sensor materials is continuing with emphasis on the molecular beam epitaxy (MBE) method. Investigation of depositing device quality layers on dissimilar substrates will continue. A selection is being made between the use of cadmium telluride (CT) or other materials for large area substrates for epitaxial growth of MCT for manufacturing purposes. Systematic doping of multilayered structures by stoichiometric adjustment and introduction of active impurities is being extensively studied. Homojunction and heterojunction structures will be grown in situ, without annealing. Through the use of electrical and optical diagnostic techniques and the development of microscopic theory, work is being initiated to explore the effects of material and processing induced defects on molecular beam epitaxy

Project: #ES-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: Electronic Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

(MBE) grown structures such as Junction diodes. Infrared detector and multi-layer superlattice devices of cadmium telluride (CT), mercury telluride (MT), mercury cadmium telluride (MCT), mercury zinc telluride (MZT) and other II-VI alloys are being prepared and evaluated. These layered structures are prepared by conventional and photon-assisted MBE and metal-organic chemical vapor deposition (MO-CVD). Research on the growth of the dilute magnetic semiconductor mercury manganese telluride (MMT) and related compounds to study and exploit their infrared (IR) and magnetic properties is continuing. The feasibility of utilizing wide bandgap MCT for fabricating high speed optoelectronic devices capable of near IR operation is being explored. Work on the monolithic integration of MCT detectors and signal processing circuitry is being initiated.

Materials and device research programs to develop laser source and detector technology for optical satellite communications are expanding. This involves the use of molecular beam epitaxy (MBE) and/or metal-organic chemical vapor deposition (MOCVD) to fabricate novel heterojunction devices and monolithic optoelectronic circuits in the III-V semiconductor materials.

The optical materials program to create improved photorefractive materials for light modulation and nonlinear materials for optical switching is continuing. Organic polymeric materials are being incorporated into device structures to determine operating characteristics. Increased emphasis is being placed on the nonlinear optical characterization, especially the third order susceptibility, of both the inorganic insulator materials and the organic polymeric materials. Work is continuing on optical processing architectures and algorithms capable of dealing with symbolic manipulations in addition to the standard numeric computations. The inherent power of optics to perform two-dimensional correlations and to facilitate interconnects between processing elements is being investigated for its potential for enhancing such symbolic operations as searching, matching, and sorting. Work is being initiated into the use of optical beam mixing to produce rapidly reconfigurable gratings which can perform switching and beam steering operations necessary for optical computing functions. These will be ultra high speed operations since they involve all-optical interactions rather than electro-optical effects.

Project: #ES-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: Electronic Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

Research is exploring such areas as gallium-arsenide-on-silicon heteroepitaxy, very-high-speed tunneling transistors, and materials characterization techniques. Exploration of superlattice and other small-dimension structures for novel electronic and optoelectronic applications continues.

Fabrication and test of hybrid acoustic charge transport (ACT) feasibility models of the following are being completed: analog-digital interface (6 bit, 400 megasamples per seconds (MSPS)); analog memory (400 megahertz (MHz) bandwidth, 40 decibel (dB) dynamic range and 12.5 microsec hold); stationary vector processor (200 MHz, 60 dB, 256 time bandwidth product); psuedo noise correlator (80 MHz, 50 dB, 400 processing gain); adaptive vector processor (200 MHz, 60 dB, 256 time bandwidth product).

c. FY 1988 Planned Program and Basis for FY 1988 Request: Device designs that have yielded successful demonstrations of millimeter-wave operation will be used in monolithic implementations that contain both the active and passive devices needed for monolithic millimeter wave (mm-wave) phased array modules. Monomolecular Langmuir-Blodgett films will be applied to novel materials and device structures to evaluate the passivation potential of these films. High vacuum, in-situ fabrication of submicrometer integrated circuits by combining various beam processing concepts in one interconnected system will be continued.

Revolutionary electronic and optoelectronic device concepts will be explored based on the results of earlier investigations of materials and heterostructures. Potential applications of semiconductor superlattices, in which scientists can tailor crystal properties as desired by adjusting material compositions and layer thicknesses, will be identified.

Development of processing technology for submicrometer feature sized digital and analog circuits will continue, as will exploration of electronic and optical polymers for unique properties of significance to DoD applications and optical techniques for symbolic computing.

Research in optoelectronics will be directed toward enhancing the interfaces between optical and digital systems, with a focus on improving architectural linkages, identifying the appropriate

electronic/optical conversion points for various problem domains, and concurrently developing algorithms with data representations for optical processing which are more compatible at the output with digital formats.

After completion of hybrid acoustic charge transport (ACT) devices, major attention will be focussed on completing monolithic fabrication of interface and processing circuits directly on the same gallium arsenide (GaAs) substrate with the ACT device. This will significantly improve the interface coupling loss and radio frequency feedthrough as well as provide the basis for economical mass production using more standard GaAs integrated circuit processing techniques.

d. FY 1989 Planned Program and Basis for FY 1989 Request: A materials and device research program will be initiated to pursue a wide variety of very inexpensive, fiber based elements for use as sensors on intelligent systems (e.g., sensors for temperature, pressure, imaging, sonar, deformation, volume, integrity, etc.)

Materials and device processing technology for the development of monolithic millimeter wave phased arrays will continue. The emphasis will remain on the investigation of new materials processing techniques and measurement which promise higher frequency and other performance advantages such as improved power-added efficiency for power amplifiers.

Materials and processing research will be continued on the development of reliable, single mode, high power, high modulation rate laser diodes and arrays as well as other optoelectronic components such as integrated receivers needed for optical satellite communications.

Investigations of devices based on superlattices and other small-dimension structures will continue. Methods of integrating novel devices into current integrated-circuit technology will be explored.

Development will continue on monolithic ACT technology along with completion and testing of the hybrid feasibility model of the programmable vector processor.

Project: #ES-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: Electronic Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

e. Program to Completion: Research efforts exploring the feasibility of specific new concepts in devices and materials within the Electronic Sciences Project generally have a duration of three to six years. New efforts will be expanded in technology applications of monomolecular films, superlattices, electronic polymers, and three dimensional circuit structures. Exploration of revolutionary in-situ, high vacuum integrated circuit fabrication will be required to keep the lead in electronics from evaporating, since conventional processing technology cannot be pushed in an evolutionary manner to tenth micrometer dimensions. The submicron materials and device physics effort will continue in FY 1990 and beyond due to the far-reaching operational significance which accompanies success, and the extreme technical challenge involved. Efforts in extremely high frequency device and material structures will continue beyond FY 1990 due to their emerging importance in super-computation, and secure communications as well as electronic warfare. Monolithic integration of optimized acoustic charge transport (ACT) devices with control and interface circuitry to form practical Analog/Digital array processors will be completed during FY 1990.

f. Milestones: The milestones reported in the FY 1987 Descriptive Summary have been completed or are expected to be completed on schedule except as noted below:

Last Year's Reported Plan	Current Plan	Milestones
--	Mid FY 1987	Demonstrate an all-optical modulator in an organic nonlinear optical material.
--	Late FY 1987	Demonstrate 94 gigahertz Permeable Base Transistor Amplifier.
Mid FY 1987	Late FY 1987	Complete fabrication and test of acoustic charge transport (ACT) hybrid devices.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #ES-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: Electronic Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestones
Early FY 1988	Early FY 1988	Demonstration of device quality polymeric alloys for low power, electro-optic devices.
--	Late FY 1988	Complete evaluation of alternative mercury telluride systems for improved infrared detecting material systems vis-a-vis mercury cadmium telluride.
--	Late FY 1988	Complete fabrication and test of acoustic charge transfer (ACT) monolithic devices.
--	Early FY 1989	Demonstrate an optical inference machine based on either matched filtering or template matching.
--	Early FY 1989	Demonstrate the growth of gallium arsenide (GaAs) thin films on silicon substrates usi: ow temperature beam processing.
--	Late FY 1989	Demonstrate Optical S-parameter measurement capability for 100 gigahertz transistor evaluation.
--	Late FY 1990	Demonstration of Stark-effect transistor.

g. Explanation of Milestone Changes: The schedule changes for achieving acoustic charge transfer (ACT) circuits is due to the difficulties in realizing this brand new challenging technology that nevertheless is achieving amazing performance.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #DRH-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: System Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The goal of this project is to develop the sciences that form the basis for technological aids to augment the performance of Department of Defense personnel. Problems that have been addressed include design of control systems for adaptive suspension and other complex vehicles, the development of advanced bio-chemical technology to allow large scale production of biological materials and structures with novel physical and chemical properties leading to the enhanced performance of man-made devices and systems, and the development of innovative mathematical methods to enhance our scientific capabilities.

The adaptive vehicle technology project will provide a new controls and capabilities for land-based travel over previously inaccessible terrain using a new control system that (1) anticipates the future path using a laser terrain mapper, (2) relieves the operator of responding to the details of that terrain, and (3) adapts the suspension of the land based vehicle to accommodate to the terrain. Preliminary data to date demonstrates major mobility improvements, e.g., a doubling of maximum speed of travel over rough terrain.

The advanced biochemical technology effort involves: the synthesis of biological materials and structures and the characterization of their novel physical and chemical properties; the solution of problems central to large-scale material production and processing; and the structural and functional integration of unconventional materials and components in device and system applications. Applications include the development of ultra-sensitive and ultraspecific strategic and tactical chemical sensors; the in-situ synthesis and exploitation of novel biopolymers for enhanced submarine speed, stealth, and (acoustic) sensor performance; the development of advanced neural-analog computer architectures and high density, fault-tolerant, content-addressable information storage devices; the production of novel micron/submicron scale self-organizing, polymerizable lipid structures for diverse optical, electronic, and composite applications; and the fabrication of molecular electronic/electro-optical devices and structures.

Project: #DRH-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: System Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

DARPA's Applied and Computational Mathematics Program (ACMP) pursues innovative mathematical research important for solving critical scientific problems such as improved design capability for military vehicles (submarines and aircraft), increased combustion efficiencies, and the theory, algorithms and computing technology that will support the next generation of radar systems.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: In the area of adaptive platforms for land-based travel, the test and evaluation program for the full-scale hexapod vehicle was initiated. This vehicle took its first steps in January 1986 and by the fourth quarter FY 1986 three modes of operation had been tested with the vehicle in an untethered state. Speeds up to four kilometer per hour were achieved. The work on a dynamically balanced quadruped was extended to include galloping and trotting. A turbine/flywheel system was completed as an alternative prime mover/storage system for the hexapod. Design studies for a full-scale autonomous quadruped were initiated.

Work towards automating the exploitation of synthetic aperture radar imagery included subsystem prototype demonstrations of vehicle detection, vehicle classification, contextual and collateral analysis, and force structure analysis and completion of the design for a prototype system.

Work in biochemical technology put emphasis on material synthesis, characterization, and early system design and evaluation. Significant accomplishments include: the identification of electron tunneling through gaps in the immune layer as the primary mechanism for operation of the quantum liquid-field chemical sensor; the demonstration of power gain at frequencies up to 1 kilohertz for molecule-based microelectronic devices; the initial feasibility demonstration of the basic silicon sensor technology underlying development of the generic solid-state multisensor; the development and successful evaluation of a working model relating polymer primary structure and hydrodynamic behavior; the development of the "viral challenge" methodology for the high level screening and (obligatory) production of microbial drag-reducing exopolysaccharides; the completion of basic bioreactor design studies demonstrating that only convective-flow immobilized-cell fermenters are capable of achieving required

Project: #DRH-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: System Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

volumetric polymer productivities; the demonstration that simple monolayer surfactant materials deposited at the air-sea interface could be used to significantly reduce (6-10 decibels) surface-generated, broad-band, acoustic noise inhibiting the performance of passive acoustic detection arrays; the completion of the Mark 4 advanc[illegible] neural processor (simulation engine) and initial feasibility demonstration in a helicopter classificati[illegible] problem (using doppler radar spectrum and spatio-temporal alloys to provide a superior ballast resist material electronic embodiments of advanced neural networks; the demonstration that polymerized lipid particles may be aligned by both flow and electromagnetic fields; the identification of 18 lipid monomer homologs all capable of forming polymerizable tubular structures; the development of new classes of hetero-bi-functional monomers allowing enhanced tubule polymerization for increased strength; and the demonstration that water, solvent, and solute concentrations and temperature may be manipulated to modify particle dimensional distribution functions.

The Applied and Computational Mathematics Program accomplishments include: A "cheaters" homotopy algorithm for finding all finite solutions of N nonlinear polynomial equations, as well as classification theorems (the benefits of homotopy methods are that it offers an improvement in speed by 8 or 10 to 1 relative existing methods); a complete description of the bifurcation set for the completion exponential family, this includes a software package for experimentation in dynamics, and the novel use of film and video techniques to study changes in dynamical systems; and development of robust methods to determine stability bounds and optimizing control over rigid bodies with one flexible appendage.

b. FY 1987 Program: Outdoor testing of the hexapod vehicle is being completed featuring demonstrations in rugged locations and evaluations by military personnel. Work is continuing on an artificial intelligence based navigation system which is necessary in order for the walking machine to operate faster over a wider variety of surfaces. Animate systems research is being initiated in order to understand the control of cooperative behavior for groups of vehicles. Software for the following modes of operation is being evaluated for the walking machine: close maneuvering, cruise, dash, and terrain following.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #DRH-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: System Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

Work in advanced biochemical technology focuses efforts on material synthesis, characterization, large-scale production, and device exploitation. Work in chemical sensor research emphasizes the design and fabrication of generic multiple-assay solid-state devices capable of diverse chemical agent, pathogen, and (unknown) toxin detection. Work with viscoelastic biopolymers continues theoretical studies of the relationship between biopolymer structure and hydrodynamic behavior and is completing experimental studies of convective immobilized-cell bioreactor design. Work on (bio) polymer synthesis exploits the viral challenge methodology to produce exopolysaccharides whose monomer sequence and linkage characteristics can be rationally controlled. Work with ocean surface artificial films is evaluating their impact on ambient and reverberation limited active acoustic arrays. Adaptive neural network research is putting emphasis on demonstrations of practical utility against real world data. Work with self-organizing lipid structures put stress on particle encapsulation, decoration and coating, alignment and orientation, matrix compatibility and embedding, and evaluation of material utility in diverse optical, electronic, and composite material applications.

The Applied and Computational Mathematics PrograM (ACMP) addresses the following: Nonlinear dynamical systems and turbulent flow in fluid dynamics efforts are developing methodologies to describe, predict and control turbulent and chaotic behavior, and the nonlinear stability of plasma and fluid dynamics, (their achievement will provide for improved military vehicle design, drag control, and the characterization of surface and subsurface wakes); development of robust methods to find stability bounds and optimize control over rigid bodies with one more than one flexible appendages; and development of theory, algorithms and software to transform complicated infinite dimensional systems (fluid flows) to simpler finite dimensional ones whose behavior can be investigated via computers. New FY 1987 initiates include development of theory and parallel algorithms for nondestructive testing of aircraft design; detect buried objects beneath the earth's surface; determine the shape of a structure to maximize its strength under a give load; and provide computing technology to support next generation radar system, e.g., low probability intercept (LPI) radar and adaptive beam-forming for anti-jamming radars in electronic warfare.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #DRH-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: System Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

c. FY 1988 Planned and Basis for FY 1988 Request: Several activities associated with achieving a fast, agile four legged vehicle will be initiated along with efforts to make the hexapod waling machine capable of all-weather operations. Research will continue on the control of small dynamically balanced quadruped vehicles. Also continuing will be the research in the use of biological performance enhancement, advanced neural network computer architecture, high-density information storage devices, novel self-organizing structures for optical, electronic, and composite materials applications, enhanced ocean surveillance, novel high performance electronic materials, and the fabrication of molecular electronic and electro-optical devices. Work in advanced chemical sensor technology will demonstrate the successful operation of the membrance-solid phase ELISA assays exploiting silicon sensors. Work with self-organizing lipid structures will yield the synthesis of non-diacetelynic tubule-forming monomers and intermediate-scale production of DC23PC lipids. Work with content-addressable, high density memories will lead to the selection of optimal switching materials and device structures for the thresholding functions.

The Applied and Computational Mathematics Program (ACMP) will begin new initiatives in dynamical systems, turbulent flow in fluid dynamics, computational algorithms, and radar algorithms, as well as expanding on previous work. One of the new initiatives is the Digital Wind Tunnel (DWT). A digital wind tunnel was impossible to undertake previously due to lack of accurate mathematical models of turbulence and lack of computer power. The ACMP will develop the required models and employ state of the are computers. Specific tasks include: A geometric approach for the solution of singular perturbation problems as well as reaction diffusion equations; development of inertial manifold techniques; a software system for the analysis of dynamical systems; development of methods to determine when data represents a smooth dynamical system, and whether numerical simulation represents chaotic behavior or is noise; continuation of work to aid in design and testing of structures, and for the analysis of fluid flows over complex structures.

d. FY 1989 Planned Program and Basis for FY 1989 Request: The agile four legged walking machine will continue with work aimed at producing speed up to twenty miles per hour. Research will continue through FY 1989 in the use of biological and quasi-biological materials and structures in advanced

Project: #DRH-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: System Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

chemical sensor technology, submarine performance enhancement, advanced neural network applications, high density information storage, enhanced ocean surveillance, and the fabrication of novel optical, electronic, and composite materials and devices. Work should demonstrate incorporation of proteins into planar lipid bi-layers; production of covalently decortable lipid tubules; completion of "neural network" microswitch fabrication and testing; completion of prototype electronic "neuron", completion of microswitch array layout, feedback and neuron interfacing, and input/output circuitry and memory evaluation.

The Applied and Computational Mathematic Program will continue the initiatives started in FY 1987 and FY 1988 in dynamical systems, turbulent follow in fluid dynamics, computational algorithms and radar algorithms, and the digital wind tunnel. New initiatives will address the following objectives: To continue development of a software system for analysis of dynamical systems by developing robust, menu driven codes for the algorithms developed in FY 1988; to provide methodologies to aid in the design and testing of structures and to find buried objects beneath the earth's surface; to provide methods to analyze fluid flows for use in the digital wind tunnel and for design of aircraft, to implement, test and analyze hybrid vortex methods; and to provide advanced computing technology to support the next generation radar systems.

e. Program to Completion: Innovative vehicular concepts to enhance mobility in adverse terrain are of long term significance to DoD. New concepts for chemical/biological sensors, adhesives, electro-magnetic materials, etc., will present themselves due to the rapid pace of biotechnology development. More efficient mathematical tools are sorely needed for computational and modelling (predictive) purposes in all science and engineering fields pertinent to DoD. Consequently, this project will be a continuing one to explore opportunities in all three areas.

f. Milestones: The milestones reported in the FY 1987 Descriptive Summary for FY 1986 have been completed on schedule.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #DRH-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: System Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestones
Early FY 1987	Early FY 1987	Complete first ADAPT processor (the Mark 4).
--	Early FY 1987	Fully integrated walking machine with vision system.
Mid FY 1987	Mid FY 1987	Enhanced hexapod speed via turbine/flywheel prime mover.
Mid FY 1987	Mid FY 1987	Complete fermenter transport analysis.
Mid FY 1987	Mid FY 1987	Evaluate surfactant broad-band noise suppression.
Late FY 1987	Late FY 1987	Demonstrate membrane stabilization and functional utility for solid state electro-chemical systems.
--	Late FY 1987	Develop theory (normal form theory) algorithms and software for transforming complicated fluid flow systems to simpler ones.
--	Late FY 1987	Identify radar benchmarks to test parallel algorithms in order to support next generation radar systems.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #DRH-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: System Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestones
--	Mid FY 1988	Synthesis of non-diacetylenic lipids.
--	Mid FY 1988	Produce yield of 50 gram/month of DC23PC tubule forming lipid.
--	Late FY 1988	Demonstrate silicon sensor based membrane solid-phase ELISA assay.
--	Late FY 1988	Complete development and implement multi-grid methods for stress related optimization problems.
--	Early FY 1989	Demonstrate covalently decortable tubules.
--	Mid FY 1989	Demonstrate incorporation of membrance proteins into planar lipid bi-layers.
Mid FY 1989	Mid FY 1989	Initiate quadruped vehicle assembly.
--	Late FY 1989	Develop algorithms to detect buried objects-mines - below the earth's surface.

g. Explanation of Milestone Changes: None.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #DRH-1
Program Element: #61101E
USDR&E Mission Area: 530

Title: System Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

I. TEST AND EVALUATION DATA: Not Applicable.

J. COOPERATIVE AGREEMENTS: Not Applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #CCS-2
Program Element: #61101E
USDR&E Mission Area: 530

Title: Advanced Digital Structures & Network Concepts
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The objective of this project is to develop the fundamental technology in advanced digital structures and network concepts for future distributed military information processing systems. Design methodologies and computer aided design tools are being developed for Very Large-Scale Integrated technology which will reduce design time and cost over present methods and produce better designs for DoD applications. System and Network concepts are being explored for use in future Communications, Command & Control architectures which will lead to survivable systems which are easier and faster to use. User interface techniques are being developed which simplify access to distributed resources and anticipate the intent of the user. Concepts for partitioning systems are being developed whereby a system can continue to function at a usable level of capability after being split or prior to merging into an integrated system. Techniques are being developed to facilitate resource sharing among computers and provide easy construction of tailored service units by the user.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: A number of Computer Aided Design (CAD) tools were developed and/or refined, including a path programmable approach that can run on IBM PC's at the University of Utah; a reliability simulator for Very Large-Scale Integrated Circuit (VLSIC) design at Massachusetts Institute of Technology (MIT); a special language for CAD tool builders at MIT; VLSIC design macro generators at the University of Washington; a high-level logic synthesizer at University of California at Berkeley; and advanced artificial intelligence (AI) techniques at the University of California and Rutgers University. Several complex VLSIC chips were designed, including 32-bit microprocessor and digital filter chip at the University of Washington and MIPS-X in scalable 2 micron technology at Stanford University. A complete image processing system was built and demonstrated at University of California at Berkeley. Eight high performance custom chips were built for this system requiring only a total of 1.5 person years of design time. The hardware engine

Project: #CCS-2
Program Element: #61101E
USDR&E Mission Area: 530

Title: Advanced Digital Structures & Network Concepts
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

architecture was chosen for the Alpha-1 three-dimensional solid modeling system at University of Utah. A Metal Oxide Semiconductor Implementation System (MOSIS) compatible Wafer-Scale-Integration (WSI) linking technology was demonstrated by Lincoln Laboratories and several WSI architectures and CAD tools were specified and developed. Advanced computer architectures implementing a high-level application oriented towards languages were investigated. Concepts for highly parallel, fine-mesh machine architectures were demonstrated. Comprehensive probabilistic modeling of phonetic coarticulation was accomplished and used to support the highest reported phonetic accuracy in continuous speech recognition. A distributed kernel for partitioned software systems was developed; and, partitioned system operation was demonstrated. Special programs called "agents" were developed to assist the user in using partitioned systems and in dealing with unfamiliar operating systems.

b. FY 1987 Program: This year sees strong emphasis on developing different approaches to rapid turn-a-round high-level design systems. Very Large-Scale Integrated Circuit (VLSIC) architecture and design efforts will address the cooperative use of design systems by large communities of designers, either in collaboration on large projects or individually in the sharing of computing resources. Design tools based on very low cost workstations will be interfaced with local area networks and the ARPANET to access centralized facilities such as design databases and hardware accelerators. Rutgers University will work with Lincoln Laboratories for an ultra-fast gate array design system: Lincoln Laboratories is automating floor-planning/partitioning of wafer-scale systems (WSI); Princeton University is beginning development of procedural based system with high-level graphical input. The University of California at Berkeley will complete the automation of synthesis and layout applied to the symbolic processor with high-level input, called SPUR, and design a macro-cell library for real-time image processing; and, the University of Southern California will begin development of an advanced system for fault-tolerant and testable designs. Basic switch-level simulation development continues at Stanford University and Carnegie-Mellon University. Innovative architecture work for cube-connected machines continues at the California Institute of Technology. Lincoln Laboratories is designing a multiprocessor for image processing, called SIMD, and the University of Utah began development of the Alpha-1 solid modeling engine. Research in cooperative

Project: #CCS-2
Program Element: #61101E
USDR&E Mission Area: 530

Tltle: Advanced Digital Structures & Network Concepts
Tltle: Defense Research Sciences
Budget Activity: 1. Technology Base

interactive systems is providing a methodology for buildlng information servlces which share a natural, easy-to-use interface that is conslstent across different systems. Development began on user lnterfaces that maintain the underlying consistency of a workstation envlronment while customizlng that same environment for speclflc users uslng a semantic model of available functlons and data. Work in combining natural language and graphlc presentatlons began. Capabillties are being developed to incorporate continuous speech as an integral component of user lnterfaces. A modular, object-oriented, database management system extenslble to new applications is being augmented to provide priority processing of tlme-crltical data. Automated technlques for robust estimation of phoneme model parameters ls belng demonstrated. A demonstration of technlques for utilizlng computing power to enhance communlcation between staff members will be a start to a larger system that supports rapld design collaborations.

c. FY 1988 Planned Program and Basis for FY 1988 Request: Advanced computer architectures based on Composite Metal Oxlde Semlconductor (CMOS), wafer-scale technology and Gallium Arsenlde (GaAs) technology will be used to demonstrate new design capablllties made possible by local area networks and the DARPA Network (ARPANET). Emphasls wlll be placed on applying these new deslgn capabilities, with associated tools, to the creatlon of hlgh-level design systems. Development of a uniform workstation interface for use as the maln interface mechanism for the next-generation operating system, called MACH, will begin. Two trial database systems, which use an extensible system prototype will begin implementation and evaluation. In speech recognition, techniques will be developed to enhance the robustness of acoustic-phonetic features; and, techniques for exploiting durational information in speech signals ln order to incorporate phonetic constraints.

d. FY 1989 Planned Program and Basis for FY 1989 Request: Artificial Intelligence techniques will be applied to integrated design systems that use hardware accelerators to allow designers to deal with the complexity of sub-micron designs. The development of large, complex software systems will provide the application environment to demonstrate a uniform workstation user interface that is used in a very large distributed environment.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #CCS-2
Program Element: #61101E
USDR&E Mission Area: 530

Title: Advanced Digital Structures & Network Concepts
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

e. Program to Completion: Advanced silicon compiler technology will be developed and this design technology will be extended to other design disciplines. Mechanical design systems will be coupled with existing flexible manufacturing systems to demonstrate demand manufacturing of mechanical components. Emphasis will be placed on integrating total system designs to facilitate manufacture and support of total systems. Experimentation in advanced computing architectures will continue with major emphasis placed on rapid prototyping of very high performance special purpose machines. Very Large Scale Integrated architecture and design efforts will focus on development of integrated capabilities for the design, fabrication, and test of integrated circuits containing in excess of one million gates and for the rapid prototyping of systems containing circuits of this complexity. Concepts for computer aided design in electronics will be extended and applied to the mechanical design problem. Research in speech will produce connected-word speech systems that can perform simple functions such as database retrieval and machine operating system commands. Intelligent user interfaces will combine natural language and graphic outputs, and user models that anticipate work session scenarios will be implemented. Core database functions will be implemented into an extensible architecture so that results of performance measurements can be used to improve system efficiency. Operating and network management systems will result in robust, survivable systems that continue to provide local utility in the face of major global outages. Methods of using computing power to aid in collaboration for staff design and planning functions will be extended to geographically distributed domains.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #CCS-2
Program Element: #61101E
USDR&E Mission Area: 530

Title: Advanced Digital Structures & Network Concepts
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

f. Milestones: All FY 1986 milestones reported in last year's FY 1987 Descriptive Summary were completed on schedule:

Last Year's Reported Plan	Current Plan	Milestone
Mid FY 1987	Mid FY 1987	Demonstrate new concepts of using graphics for interaction with computers.
- -	Mid FY 1987	Complete design of the structure of a user interface that supports all basic interaction styles.
Late FY 1987	Late FY 1987	Demonstrate a combined lip reading and acoustic speech system that can recognize isolated words under varying ambient noise conditions.
- -	Late FY 1987	Demonstrate techniques of augmenting staff communications using interactive software support.
- -	Late FY 1987	Demonstrate wafer-scale design tools.
Late FY 1987	Late FY 1987	Demonstrate a phonetic modeling system that provides exceptionally high word accuracy for large vocabulary continuous speech.
- -	Early FY 1988	Develop a uniform workstation interface for the next-generation operating system (MACH,.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #CCS-2
Program Element: #61101E
USDR&E Mission Area: 530

Title: Advanced Digital Structures & Network Concepts
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestone
- -	Mid FY 1988	Demonstrate a system to enhance the planning and collaborative performance of a VLSIC design group.
- -	Mid FY 1988	Develop robust acoustic-phonetic features that enhance speech recognition.
- -	Mid FY 1988	Wafer-level design system demonstrated and transferred to the research community.
- -	Late FY 1989	Demonstrate a uniform workstation user interface and stress it by developing large bodies of software.

g. Explanation of Milestone Changes: None.

I. TEST AND EVALUATION DATA: Not Applicable.

J. COOPERATIVE AGREEMENTS: Not Applicable.

42

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: # CCS-3
Program Element: #61101E
USDRE Mission Area: 530

Title: Modernization Technology
Titie: Defense Research Sciences
Budget Actlvity: 1 Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: This project has four primary goals: 1) to strengthen U.S. universities' abiiity to conduct criticai fundamentai research in information processing by providing and maintaining a base of modern computing resources; 2) to deveiop computer techniques for advanced robotics; 3) to deveiop automated design techniques for application to rapid system prototyping; and (4) to develop tethered platforms and sensors. The modernization area has been highilghted by the Defense Science Board as a critical area for investment, if U.S. technoiogy leadership in information processing is to be maintained. Existing equipment, which in some cases is aimost twenty years old, is being upgraded from iarge time-sharing systems to powerfui single-user workstations configured in local networks. Experimental computer resources such as symbolic processors with large address space and high resolution graphics displays are being provided to U.S. universities performing DoD research to stimulate innovation in the fieids of artlficiai inteiiigence, Very Large Scale Integrated (VLSI) architectures, software technology, design systems, robotics, and automation technology. This effort wili continue through FY 1988. In the area of automated system design, ways in which information processing can close the gap between the generation of ideas and their concrete reaiization in the form of visuai models, physical objects, or mechanicai systems are being explored. These efforts wili emphasize the human interface issues and use of advanced manipuiators and dispiay technology. High-resolution graphics systems wili be used to aid in the description of compiex objects and to provide a graphicai representation of objects described by information structures. Research in robotics is focused on developing automated systems that can be commanded in high-ievel languages (approximated by conversationai Engiish) and have the system automaticaiiy determine subgoals needed to carry out the desired task, then reason about the detailed soquences of specific steps needed to execute the command. To meet these objectives, highly developed perceptuai and spatiai reasoning systems must be integrated with mechanical effectors. Other efforts involve development of systems for describing and transforming shape, motion, and structural information, the synthesis of complex mechanical structures, and computer representation of 3-dimensional scenes which can be derived from visual, tactile or other sensor information. Design and impiementation of real-time controllers for

Project: # CCS-3
Program Element: #61101E
USDRE Mission Area: 530

Title: Modernization Technology
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

design and implementation of real-time controllers for effective spatial manipulation of physical objects will be pursued and techniques explored to improve the productivity of scientific researchers by providing automated assistance for manual tasks which are tedious, time-consuming and/or error-prone. Perception (sensor) systems for standoff reconnaissance have tended to be limited to providing support to high levels in the military command structure because of the expense associated with platforms and sensors. A class of perception systems based on inexpensive, tethered platforms and lightweight sensors is being explored. The program will develop a technology base focused on providing front line commanders with "over the next hill" reconnaissance.

2. Program Accomplishments and Future Programs:

a. FY 1988 Accomplishments: State-of-the-art computing resources are being provided and maintained at critical research laboratories. Research in robotics will continue to focus on spatial and temporal reasoning to permit more effective planning. ALANA, Augmentable Language Analyzer, a major natural language component of the UNIX Consultant project was completed and documented for use by other research groups designing powerful interfaces to computer systems. Spatial and temporal algorithms continue to be developed that can be used for robot planning. Autonomous robotic navigation processes which use visual information from real-time 3-D scene understanding algorithms, including stereo perception, laser ranging, and optical flow techniques have been developed and demonstrated. A calibrated imaging laboratory was constructed which will provide high precision images for further research on errors introduced by algorithms for stereo, motion, shape, or photometric analysis. Stochastic sampling techniques for anti-aliasing have been demonstrated which prove effective in eliminating the jagged lines caused by digital sampling during design automation. Stochastic sampling techniques were also used for image synthesis to enhance design graphics. Graphics animation was improved by using linear small amplitude wave theory to model certain natural events such as ocean waves. Graphic animation algorithms were used to model the motion of articulated bodies such as humans and robots and they have been improved by using dynamic analysis instead of kinematic specifications. These graphics improvements lead directly to more reality in graphic displays of defense systems in simulations of active employment (e.g., flight or tank simulators,

Project: # CCS-3
Program Element: #61101E
USDRE Mission Area: 530

Title: Modernization Technology
Title: Defense Research Sciences
Budget Activity: 1 Technology Base

etc.). A program focused on the development of an inexpensive tethered reconnaissance platform and sensors to provide the front iine commander with the abiiity to "see over the next hill" was initiated.

b. FY 1987 Program: Key universities continue to be suppiied with advanced computer resources and supporting maintenance. The price/performance ratio of symboiic computers is expected to continue to provide more symboiic computing capability for the doiiar as more competitors enter this market; this will provide greater computation resources for universities and other institutions without corresponding increases in funds. In this year, more of the resources go to locations which have not received equipment in the recent past. A major concern is reai-time issues of robotic planning to insure that temporai constraints are being met. Work in robotic control and manipuiators emphasizes competence in robotic hands using new tactile sensors and point-oriented object descriptions in expioring recognition and manipulation of objects from tactiie perception. In robotic vision, basic theories for using coior as a source of knowledge are being further developed to enhance feature discrimination tasks such as detecting the edges of colored regions or identifying the highlights reflected from giossy objects. In addition, ianguages and techniques for robotic interface and instruction are being expiored to increase the band-width and generaiity of communication with robotic devices. As more basic work in robotics matures, more effort will be directed to the construction of integrated testbeds that can demonstrate the potential of the robotic technology in projects of defense interests (e.g., battlefieid robots or job shop robots for supply and maintenance). Connections between the robotics activities in this program and other DoD, NASA, and industrial projects are being explored to insure technology transfer is effective. In particuiar, much of this technology is relevant to severai nationai initiatives in automated manufacturing. The tethered reconnaissance program is developing prototype platforms which will provide the capabiiity of quickly and inexpensively elevating iightweight sensors to altitudes of up to 1000 feet. Plans for developing sensors have been changed due to funding cuts. A program which would develop a light weight, low cost, all weather, day and night radar sensor for detection of ground and air targets is being postponed until 1988.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: # CCS-3
Program Element: #61101E
USDRE Mission Area: 530

Title: Modernization Technology
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

c. FY 1988 Planned Program and Basis for FY 1988 Request: The integrated testbed in manufacturing environments will be expanded so that more complex tasks can be assigned to factory floor-roving robots as well as autonomously roving robots in dynamic battlefield environments. Work in robotic perception, manipulation,and control will progress to the point where fine discriminatory tasks such as bin picking and parts insertion will be routinely performed. Advances in robotic planning will focus on high-level instruction of robots by natural language interaction, but progress in this area is directly linked to further developments in natural language technology being pursued in other DARPA research programs (e.g., ST-10 and ST-11). The tethered reconnaissance program will deliver three prototype systems for use by the Services to evaluate techniques which provide an inexpensive platform for a variety of missions including "over the next hill" surveillance. In addition, a program will be initiated to develop and evaluate various payloads for the platform including a radar capable of supporting surveillance and threat air detection.

d. FY 1989 Planned Program and Basis for FY 1989 Request: Languages and techniques for robotic instruction will be greatly improved, but will still be short of that used to interact with human assistants. In well understood task domains, simple robotic prototypes will be demonstrated performing numerous complex perceptual and reasoning tasks with little or no direction from humans except for instruction of very general goal conditions. Emphasis will be on robotics in manufacturing tasks. Testbed activities at this time will capitalize on previous DARPA funded research in machine perception and robotic planning, but there will still be major limitations in all robotic technologies that prevent the full flexibility and general adaptability desired in robotic assistants. Development and evaluation of payloads for the tethered reconnaissance program will continue.

e. Program to Completion: Emphasis will be placed on investigations of robotic performance in unplanned scenarios. Techniques for incorporating machine learning techniques will be used to expand the adaptability of robotic systems. Robotic systems that reason about spatial quantities, use multiple representations of objects, and maneuver in and manipulate its environment will be

developed. Cooperative robotic techniques will continue to be explored and developed, as will the use of qualitative models to predict the effects of planned actions by robotic agents.

f. Milestones: FY 1988 milestones not included in this year's plan which were listed in last year's plan have been accomplished.

Last Year's Reported Plan	Current Plan	Milestone
Mid FY 1987	Mid FY 1987	Demonstrate advanced robotic planning for autonomous navigation.
Mid FY 1987	Mid FY 1987	Continue computer resource modernization.
Late FY 1987	Late FY 1987	Demonstrate initial techniques for high-level robotic instruction.
Late FY 1987	Late FY 1987	Demonstrate spatial and temporal reasoning in three dimensions.
- -	Mid FY 1988	Tethered reconnaissance platform demonstration.
Mid FY 1988	Mid FY 1988	Continue computer resource modernization.
Late FY 1988	Late FY 1988	Demonstrate spatial and temporal reasoning in dynamic environments.
- -	Late FY 1989	Tethered MTI demonstration.
Late FY 1988	Late FY 1989	Demonstrate robotic task improvement via machine learning techniques such as generalization, induction, or analogy.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: # CCS-3
Program Element: #61101E
USDRE Mission Area: 530

Title: Modernization Technology
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

g. Explanation of Milestone Changes: Not applicable.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #61103E
USDR&E Mission Area: 530

Title: University Research Initiative
Budget Activity: 1. Technology Base

A. RESOURCES: ($ in Thousands)

Project Number	Title	FY 1986 Actual	FY 1987 Estimate	FY 1988 Estimate	FY 1989 Estimate	Additional to Completion	Total Estimated Costs
	TOTAL FOR PROGRAM ELEMENT	$ 5,415	$ 8,750	$24,570	$25,000	Continuing	N/A

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This program element pursues new university based research initiatives in sciences and technologies of demonstrated or potential long term significance to the Department of Defense (DoD). The focus is on interdisciplinary research thrusts of three to five years duration which promise unique and innovative technological breakthroughs for use in the design and fabrication of future DoD systems. Particular emphasis is placed on efforts which couple computationally intense modelling and theoretical calculations exploiting the new generation of relatively low cost multiprocessor system architecture using advanced software and systems technologies with a viable experimental program to guide and verify the modelling/theory. Technical areas addressed include: fluid dynamics in physical phenomena involving the transition to turbulent flow; monomolecular and thin film multilayer metal, semiconductor, organic, and electro-optic structures exhibiting quantum and other size effects; synthesis and evaluation of structural and conducting polymers; mechanical behavior of high temperature composite materials; and applications of biotechnology to DoD needs. Each initiative addresses funding for experimental and theoretical research, and includes support for multiprocessor computational equipment and instrumentation as well as faculty, graduate fellowships and research assistantships and materials necessary to execute the project.

C. COMPARISON WITH FY 1987 DESCRIPTIVE SUMMARY: Unchanged, except for Congressionally reduced budget in FY 1987 ($8.75 million instead of $12.5 million requested).

D. OTHER APPROPRIATION FUNDS: Not Applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #61103E
USDR&E Mission Area: 530

Title: University Research Initiative
Budget Activity: 1. Technology Base

E. RELATED ACTIVITIES: Defense Research Sciences (DRS) within Army, Navy, Air Force and DARPA provides broad support to the engineering and science disciplines of long term significance to the Department of Defense. This project will strengthen the DRS efforts substantially by supporting comparatively large ($1M-$3M/year/contract) and major equipment purchases (e.g., $0.5M-$2.0M) which cannot be accommodated in existing research program structures. These multi-disciplinary efforts exploit emerging, high leverage scientific opportunities for defense needs, fill gaps in the existing national research and development program, and meet threats of foreign domination of a science or technology.

F. WORK PEFORMED BY: This project is performed by universities that were selected on a competitive basis. They are: Purdue University, Lafayette, Indiana; Pennsylvania State University, University Park, Pennsylvania; California Institute of Technology, Pasadena, California; University of Massachusetts, Amherst, Massachusetts; University of Connecticut, Storrs, Connecticut; Massachusetts Institute of Technology, Cambridge, Massachusetts; University of San Francisco, San Francisco, California; Harvard University, Cambridge, Massachusetts; University of Pennsylvania, Philadelphia, Pennsylvania; University of Texas, Arlington, Texas; University of Florida, Gainesville, Florida; University of California, Santa Barbara and San Diego, California; Case Western Reserve, Cleveland, Ohio; Rensselaer Polytechnic Institute, Troy, New York; Princeton University, Princeton, New Jersey; and Brown University, Providence, Rhode Island. There are also many universities acting as subcontractors to those listed.

G. PROJECTS LESS THAN $7 MILLION IN FY 1988: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #61103E
USDR&E Mission Area: 530

Title: University Research Initiative
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: This project explores defense relevant, innovative research concepts in the engineering and physical sciences in a sufficiently early stage of development that they are best addressed through focused, interdisciplinary, university based research initiatives. Each initiative is of three to five years duration, emphasizes funding for necessary instrumentation, and provides post-doctoral and graduate assistantships as well as other necessary support to implement its research plan. Particular emphasis is placed on initiatives which combine theoretical modelling made possible by relatively inexpensive new, multiprocessor system architectures with a robust experimental program to verify and guide the theoretical effort. Specific initiatives are selected on the basis of the opportunity to exploit emerging, high leverage scientific opportunities which address urgent defense needs, fill large gaps in the national research and development program, and meet threats of foreign technological domination.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: This project was announced and described to the academic community through a Broad Agency Announcement and briefings to the research community at conferences and other appropriate meetings. Eighteen proposals were selected for funding by a DoD-wide team of experts from a submission to DARPA of a total of 118 proposals. Awards were made in five technical areas: Fluid Dynamics, High Temperature Composite Materials, Structural and Electronic Polymers, Sub-Micron Structures, and Biotechnology. All efforts were under contract by September 30, 1986, and substantial funds immediately expended on necessary equipment purchases. The emphasis in the actions funded was on acquisition and/or design and fabrication of state-of-the-art equipment and multiprocessor systems to provide experimental and supercomputational capability necessary for the research efforts, and establishment of necessary research assistantships/fellowships.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #61103E
USDR&E Mission Area: 530

Title: University Research Initiative
Budget Activity: 1. Technology Base

b. FY 1987 Program: Major equipment purchases are being executed. Staffing (including 5 to 10 graduate students per contract) is nearly completed. An initial "kickoff" meeting was held between all contractors and DARPA and Services technical and contracting personnel to familiarize everyone with the scope of the entire project, and to initiate interdisciplinary inter-contract research cooperation. Substantial research results are being achieved during FY 1987, despite the normally long "shakedown" times needed for major new equipment acquisition and installation.

c. FY 1988 Planned Program and Basis for FY 1988 Request: During FY 1988, University Research Initiative (URI) researchers will: (1) explore growth of submicron heterostructures of diluted magnetic semiconductors by molecular beam epitaxy and atomic layer epitaxy techniques, characterize the materials, access their utility for optical imaging, computing, communications, countermeasures, and recording, and develop II-VI microstructure device concepts; (2) synthesize and characterize biopolymers based upon the primary sequence of amins acids or base pairs; (3) develop new high temperature structural and electronic polymers and polymer processing methods based upon polymer alloying and upon non oxidation-reduction processing of polyanilines, a new class of polymers with "metallic" conductivity; (4) design and develop processing routes for high temperature composites based upon micromechanical concepts for enhanced high temperature strength and stability; (5) conduct studies of chaotic and turbulent fluid dynamics in order to develop techniques for effective management and predictability of turbulent conditions, and (6) study modern problems of complex transitioned/turbulent flows to develop innovative designs for aircraft and military vehicles.

d. FY 1989 Planned Program and Basis for FY 1989 Request: It is anticipated that the effort in high temperature composites will provide new micromechanics concepts for strengthening and toughening intermetallic and ceramic matrix composites; the focus of the polymers effort on new conducting polymers with controlled conductivity is aimed at establishing novel materials for electromagnetic applications such as shielding and signature control as well as novel electronic conductors; the program on submicron structures will address new concepts in efficiency of design of highly integrated circuits and novel electronic devices; the effort in fluid dynamics will continue to

52

Program Element: #61103E
USDR&E Mission Area: 530

Title: University Research Initiative
Budget Activity: 1. Technology Base

investigate complex flow characteristics in regimes of interest for high performance air structures; the effort in biotechnology will continue to investigate the synthesis and properties of biopolymers.

e. Program to Completion: In FY 1989 research results will be accumulated and critically assessed for each project. Those showing great promise for major impact on technical capabilities significant to DoD will be continued, and their results will begin transition to exploratory development in DARPA and the Services. The program will be completed in FY 1991.

f. Milestones: All FY 1986 milestones reported in last year's FY 1987 Descriptive Summary were completed on schedule:

Last Year's Reported Plan	Current Plan	Milestone
Early FY 1987	Cancelled	Second round of proposal solicitation.
--	Early FY 1988	Completion of construction of new molecular beam expitaxy and atomic layer epitaxy facilities.
--	Mid FY 1988	Demonstrate applicability of micromechanics models to predicting failure of composites.
Late FY 1988	Late FY 1988	Evaluation of progress on FY 1986 contracts and selection of those for continued support.
--	Late FY 1988	Development completed on macromolecular work bench
--	Late FY 1988	Complete processing laboratory for intelligent processing of high temperature polymers.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #61103E
USDR&E Mission Area: 530

Title: University Research Initiative
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestone
--	Mid FY 1989	Create new ionic liquid crystalline polymers for large aperature optical devices for high power lasers.
--	Late FY 1989	Complete development of diluted magnetic semiconductor designs and initial processing techniques.
--	Late FY 1989	Develop novel tecnniques for protein synthesis
--	Late FY 1989	Demonstrate applicability of surface characterization techniques to predict composite behavior.

g. Explanation of Milestone Changes: A second round of proposal solicitation has been cancelled due to funding restraints.

I. TEST AND EVALUATION DATA: Not Applicable.

J. COOPERATIVE AGREEMENTS: Not Applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element. #62101E
USDR&E Mission Area: 530

Title: Technical Studies
Budget Activity: 1. Technology Base

A. RESOURCES: ($ in Thousands)

Project Number	Title	FY 1986 Actual	FY 1987 Estimate	FY 1988 Estimate	FY 1989 Estimate	Additional to Completion	Total Estimated Cost
	TOTAL FOR PROGRAM ELEMENT	$1,500	0	$1,700	$1,800	Continuing	N/A

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This program provides independent, topical, in-depth studies and analyses in support of the Office of the Under Secretary of Defense for Research and Engineering (OUSDR&E), and its various component offices. Each year the most urgent subjects are chosen by the directors of Strategic and Theater Nuclear Forces, Tactical Warfare, Research and Advanced Technology and others. The Institute for Defense Analyses (IDA) provides in-depth answers to current and anticipated future problems assisting the decision makers to make better informed judgements and decisions.

C. COMPARISON WITH FY 1987 DESCRIPTIVE SUMMARY: New areas of research to be added include National Aerospace Plane support; space transport systems; future close support aircraft; emerging technologies options; and improvements in survivability, supportability and effectiveness of future tactical and strategic forces. No funds were required in FY 1987 due to planned late obligation of FY 1985 and FY 1986 funds.

D. OTHER APPROPRIATION FUNDS: None.

E. RELATED ACTIVITIES: The work performed under this program element is related to and contributes data to the program management activities of OUSDR&E. Specific offices that have been supported include those of the Deputy Under Secretaries, Defense Research and Engineering (DUSDR&E) for: Research and Advanced Technology; Tactical Warfare Programs; Strategic and Theater Nuclear Forces; and International Programs and Technology.

F. WORK PERFORMED BY: This research is performed by the Institute for Defense Analyses (IDA), Arlington, Virginia (FFRDC, 100%).

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62101E
USDR&E Mission Area: 530

Title: Technical Studies
Budget Activity: 1. Technology Base

G. PROJECTS LESS THAN $7 MILLION IN FY 1988-1989: The Institute for Defense Analyses has completed or is about to complete all Project Assignments planned for FY 1986. These include: (1) National Security Strategies (forces planning and strategic competition), (2) Combat and Combat Support Systems (strategic warfare, non-strategic nuclear forces & C³I, chemical warfare, advanced conventional weapons, tactical C³I and counter-C³I), (3) Defense Planning and Management (technology base study program), (4) Advanced Computing Technology, (5) Pacific Basin and National Security, and (6) USSR as a Responsive Threat. The OUSDR&E plans for IDA work in FY 1987 include studies in Electronic Technologies for Surveillance and Target Acquisition, Evaluation of Air Delivered Chemical Weapons, Strategic Options as a Response to Soviet Non-Compliance, Space Transportation Systems Analysis, Aerospace Plane Technology, Future Close Air Support Alternatives, Competent Munitions and several other topics now being defined. Program plans for FY 1988 and FY 1989 are not fully formulated at this time. However, it is envisioned that some work will be extensions of work initiated in FY 1987. Political and military situations that may develop between now and FY 1989 may necessitate rapid revisions. Tentative plans envision studies in multi-mission remotely piloted vehicles, defensive systems for airlifts, USA/USSR defense research and development comparisons, tactical warfare air defense studies and assessment of the directed energy susceptibility/vulnerability/lethality of developmental/production or deployed flight critical military aircraft structural components. This is a continuing program with no set completion target.

H. PROJECTS OVER $7 MILLION IN FY 1988: Not Applicable.

I. TEST AND EVALUATION DATA: Not Applicable.

J. COOPERATIVE AGREEMENTS: Not Applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Technology
Budget Activity: 1. Technology Base

A. RESOURCES: ($ in Thousands)

Project Number	Title	FY 1986 Actual	FY 1987 Estimate	FY 1988 Estimate	FY 1989 Estimate	Additional To Completion	Total Estimated Costs
	* TOTAL FOR PROGRAM ELEMENT	206,941	216,960	233,950	256,100	Continuing	N/A
ST-1	Advanced Strategic Concepts & Strategic Technical Analysis	3,820	21,825	16,600	17,654	Continuing	N/A
ST-5	Hypersonic Technology	17,240	-0-	-0-	-0-	-0-	N/A
ST-7	Special Applications Technology	5,780	-0-	-0-	-0-	-0-	N/A
ST-9	Submarine Laser Communications	25,867	12,445	-0-	-0-	-0-	N/A
ST-10	Strategic Computing	115,728	104,360	120,200	133,126	Continuing	N/A
ST-11	Intelligent Systems	21,857	27,540	30,170	33,200	Continuing	N/A
ST-12	Quantum Electro-Optics	11,371	18,240	33,770	34,000	Continuing	N/A
ST-13	Strategic Air Cruise Missile Defense	4,825	7,150	7,510	12,675	Continuing	N/A

* Totals include classified projects not identified herein

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Technology
Budget Activity: 1. Technology Base

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This Program Element in FY 1988 and FY 1989 funds a varied and broad research and development program directed toward the development and application of advanced technologies associated with strategic system concepts; strategic communications and signal processing; blue-green lasers; strategic computing; intelligent systems; advanced electro-optics; and advanced aircraft and cruise missile surveillance and engagement techniques.

This is the only program within DoD which identifies and explores innovative technologies for new strategic missions. Without this broad and comprehensive research and development (R&D) Program, no non-nuclear strategic capability will ever be achieved. Accordingly, DARPA has directed this program toward the development and application of the above technologies associated with advanced strategic system concepts including new space initiatives.

The Advanced Strategic Concepts and Technical Analysis Project identifies and evaluates advanced strategic system concepts and system technologies in order to define critical technological issues and establish experimental efforts which could significantly alter military effectiveness. This project supports the Under Secretary of Defense for Acquisition (USD-A) and his Director of Defense Research and Engineering (DDR&E) in establishing feasibility and priorities on present and proposed R&D programs and to technically evaluate the technological and capability implications of various treaty provisions. Other new initiatives supported within this project include counter-terrorism, an artificial gill for oxygen extraction applications, an advanced electro-optical processing concept entitled Clutter Rejection Optical Pre-Processing (CROPP), a Space Object Assisted Recovery (SOAR) concept and advanced electronic counter countermeasure (ECCM) techniques for space radar applications.

The Hypersonic Flight Technology project developed technologies in airbreathing propulsion; strong, lightweight, high temperature materials; and cryogenic hydrogen utilization. These technologies are applicable to the next generation strategic vehicles having capabilities to fly within the atmosphere at unprecedented speeds and altitudes. This project was terminated in FY 1986 and its efforts transferred to the National Aerospace Plane Program Element (PE 63269E) in FY 1987 and to the Air Force in FY 1988 and beyond.

The Special Application Technology Project terminated in FY 1986 and consisted of two thrusts: Strategic Communications and the Acoustic Charge Transport (ACT). Strategic Communications was transferred in FY 1986 to the Strategic Concepts and Analysis Project (ST-01). The Acoustic Charge Transport (ACT) program was transferred to Program Element 61101E, Project ES-01.

The Submarine Laser Communications Project developed technology to provide future improvements in the Submarine Laser Communication (SLC) systems which will be transferred to the Navy in FY 1987. These technologies offer an order of

magnitude improvement in communications to and from submarines over the basic technology which previous work under this line has shown to be feasible and ready for engineering development in the Navy.

The Strategic Computing Project is an effort to develop and demonstrate super intelligent computers for application to critical problems in defense. It draws directly on the research results from the Intelligent Systems Project (ST-11), and augments them to provide specific future defense capabilities using advanced computer technology.

The Intelligent Systems Project undertakes fundamental investigations into the limits of the digital computer's capabilities for intelligent processing in selected areas of military relevance. The results of this research are to be exploited in the Strategic Computing Project (ST-10).

The Advanced Quantum Electro-Optics project is developing unconventional atmospheric compensation technologies, nonlinear optics technology and advanced materials, sensors and laser technology to make possible a broad range of new military capabilities including high-resolution,long-range imaging of space objects from the ground, long range endoatmospheric imaging systems, and space-based and airborne optical detection. Sensor protection against in-band laser threats will be initiated.

Strategic Air Cruise Missile (SACM) Defense Project objectives are to identify and to develop techniques for surveillance and engagement of aircraft and cruise missiles. Potential threat vehicles also include satellites. Mission functions addressed include surveillance (acquisition, track, identification), targeting and kill assessment. The SACM Program will develop system concepts, associated technologies, and an architecture to provide the building blocks for advanced strategic surveillance capability. The goal is to achieve an order-of-magnitude sensitivity improvement compared to existing surveillance systems.

C. COMPARISON WITH FY 1987 DESCRIPTIVE SUMMARY:

Advanced Strategic Concepts and Strategic Technical Analysis - FY 1987 funding increased due to redistribution of several efforts into this project and additional requirements in the areas of strategic relocatable targets and enhanced lethality/zero Circular Error Propable (CEP) weapons; FY 1988 funding increases only 6%; FY 1989 increases by less than 3%.

Hypersonic Flight Technology - As indicated previously, this project has transitioned to new Program Element (63269E) in FY 1987 where the FY 1987 and 1988 comparison is addressed.

Special Applications Technology - FY 1986 and out year funding has been eliminated due to the programs transfer to other projects described earlier.

Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Technology
Budget Activity: 1. Technology Base

Submarine Laser Communications - As indicated previously, this project will be transferred to the Navy in FY 1987.

Strategic Computing - FY 1986 through FY 1989 funding has decreased due to Congressional and Defense Department budget reductions.

Advanced Quantum Electro-Optics - Many new starts described in the FY 1987 RDT&E Descriptive Summary were postponed or deleted due to Gramm-Rudman budget reductions and other undistributed cuts. External funds from SDIO enabled DARPA to resume the responsibility from SDIO of conducting experiments and developing the technology for atmospheric compensation efforts. The increase in funding in FY 1988 and FY 1989 results from two reasons. First, this project will bear the full financial burden of the atmospheric compensation technology because SDIO assistance will end. Second, this project will fund new, near-term field experiments at existing government telescope facilities to exploit recent breakthroughs in atmospheric compensation.

Strategic Air Cruise Missile (SACM) Defense - FY 1987-1988 funding decreases are due to budget reductions and project restructuring. FY 1989 funding increases are to support concept demonstrations and component technology development of selected SACM technologies.

D. OTHER APPROPRIATION FUNDS: Not applicable.

E. RELATED ACTIVITIES:

The Advanced Strategic Concepts and Technical Analysis project relates directly to programs of the Under Secretary of Defense for Acquisition (USD(A)), the Air Force Aeronautical Systems Division, the Army Strategic Defense Command, the Air Force Strategic Air Command, the Air Force Ballistic Missile Office, the Naval Research Laboratories, the Air Force Space Division, the United Space Command, and the Air Force Rome Air Development Center.

In Strategic Computing the Defense Software Technology Initiative will augment this effort by developing single processor software environments based on the Ada Programming language and by providing Ada programming support environments to support conventional software practices. The Very High Speed Integrated Circuit program is addressing special purpose Very Large Scale Integrated (VLSI) chips for military signal processing applications. The S-1 multiprocessor system under development by the Navy and Department of Energy is exploring one approach to multiprocessor architecture potentially useful for superspeed computer applications. National Bureau of Standards will support maintenance and dissemination of speech databases developed under this program to the research community at large and will support multiprocessor system architecture benchmarking activities. The Services, National Security Agency, and Central Intelligence Agency have all initiated Artificial Intelligence (AI) Centers that offer the potential of contributing technology to, and using the

technology developed by the generic AI component of this effort. The Supercomputer Research Division of Institute for Defense Analyses, established by DoD, will assist in the evaluation of selected multiprocessor system architectures.

Intelligent Systems: The National Science Foundation, the National Institute of Health, the National Aeronautics and Space Administration, the Office of Naval Research, the Air Force Office of Scientific Research, the Naval Research Laboratory, the Naval Electronic Systems Command, the Defense Mapping Agency, Rome Air Development Center, the Army Engineering Topographic Laboratory, and Air Force Avionics Laboratory also support artificial intelligence research. These efforts address image understanding, expert systems technology, industrial automation, analytical chemistry, immunology, natural language understanding, deep-space and undersea probes, information fusion, and management decision aids. Techniques developed in this project have widespread applicability throughout the Defense Department. Close coordination with prospective users is maintained through workshops, site visits, the choice of contracting agents, and joint programs. Examples of joint programs include the image understanding and natural language database interface work being performed in conjunction with the Defense Mapping Agency and the image understanding for port monitoring work conducted with the Central Intelligence Agency and Office of Naval Research. In the area of software generation, the Ada Joint Projects Office (AJPO) is funding work in software engineering and a new government Software Engineering Institute is to be developed. DARPA's work in new-generation software development involves more advanced research and complements the other software engineering work described above.

Advanced Quantum Electro-Optics: The development of unconventional atmospheric compensation technology and high-resolution, deep-space imaging will be fully coordinated through technical interchange meetings and agent contracting activities with related Air Force programs currently on-going at Rome Air Development Center, Air Force Weapons Laboratory, Air Force Space Division and Air Force Space Command.

Sensor protection programs exist in the Services which apply existing techniques to fielded systems. This program would develop new technology specifically aimed at the in-band frequency-agile laser threat, which cannot be countered by existing technology.

The Strategic Air Cruise Missile Defense project directly supports the Air Defense Initiative and related projects within the Air Force (Lead Service), Army, Navy and Strategic Defense Initiative Organization (SDIO).

F. WORK PERFORMED BY:

Advanced Strategic Concepts and Strategic Technical Analysis: All of the project efforts are conducted by industry. The major contractors are: General Research Corporation, Santa Barbara, California; Toyon Research, Santa Barbara, California; Analytical Decisions, Inc., Arlington, Virginia; MIT Lincoln Laboratory, Lexington, Massachusetts; Vanguard Research Incorporated, Fairfax, Virginia; Development Systems and Research Corporation, Fairfax, Virginia; Aquanautics

Corporation, Emeryville, California; ERIM, Ann Arbor, Michigan; Science Applications International Corporation, various locations; Harris, Melbourne, Florida; and TRW, Los Angeles, California.

Strategic Computing: 43% University, 43% Industry, and 14% In-House. The major performers are Bolt Beranek and Newman, Cambridge, Massachusetts; Carnegie-Mellon University, Pittsburgh, Fittsburgh; Columbia University, New York City, New York; Martin-Marietta Corp, Denver, Colorado; Massachusetts Institute of Technology, Cambridge, Massachusetts; MIT Lincoln Laboratory, Lexington, Massachusetts; National Bureau of Standards, Gaithersburg, Maryland; Naval Ocean Systems Center, San Diego, California; Rockwell International, Thousand Oaks, California; Stanford University, Stanford, California; Texas Instruments, Inc., Dallas, Texas; Thinking Machines, Inc., Cambridge, Massachusetts; University of Maryland, College Park, Maryland; and University of Southern California, Information Sciences Institute, Marina Del Ray, California.

Intelligent Systems: 35% Industry, 58% University, 7% In-House. Major performers are Bolt Beranek and Newman, Cambridge, Massachusetts; Carnegie-Mellon University, Pittsburgh, Pennsylvania; Columbia University, New York City, New York; Environmental Research Institute of Michigan, Lansing, Michigan; ESL, Inc., Mountain View, California; Hughes Research Lab., Malibu, California; Kestrel Institute, Palo Alto, California; Massachusetts Institute of Technology, Cambridge, Massachusetts; Rutgers University, New Brunswick, New Jersey; Rand Corp., Santa Monica, California; SRI International, Menlo Park, California; Stanford University, Stanford, California; University of California, Berkeley, California; University of Massachusetts, Amherst, Massachusetts; University of Rochester, Rochester, New York; University of Southern California, Los Angeles, California; and Yale University, New Haven, Connecticut.

Advanced Quantum Electro-Optics: It is anticipated that 60% of this effort will be conducted by industry, 30% by universities and 10% by government laboratories. The current and anticipated participants include Itek Corporation, Lexington, Massachusetts; United Technology Research Center, AVCO, Everett, Massachusetts; Optical Sciences Co., Riverside Research Institute, Arlington, Virginia; Hughes Research Laboratory, El Segundo, California; Sanders Associates, Nashua, New Hampshire; Westinghouse Research Laborabory, TRW, Redondo Beach, California; Spectra Technology, Inc., Science Applications International Corporation, Atlanta, Georgia; M.I.T. Lincoln Laboratory, Lexington, Massachusetts; University of Michigan, Ann Arbor, Michigan; University of Arizona, Tuscon, Arizona; Naval Research Laboratory, Washington, D.C.; and Air Force Weapons Laboratory, Albuquerque, New Mexico.

Strategic Air and Cruise Missile Defense Project: Industrial contractors comprise 95% of the effort with the remainder performed by the Institute for Defense Analysis, Alexandria, Virginia. Major contractors are: General Dynamics, San Diego, California; Westinghouse, Columbia, Maryland; Decision Science Applications, Arlington, Virginia; Research and Development Laboratories, Culver City, California; Photon Research Associates, Riverside Research Institute, Arlington, Virginia; Science Applications Incorporated, La Jolla, California; Simulation Technology Incorporated, Lockheed Missile Systems Corporation, Sunnyvale, California; Environmental Research Institute of Michigan (ERIM), Ann Arbor, Michigan; and SRS Technologies, Arlington, Virginia.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Technology
Budget Activity: 1. Technology Base

G. PROJECTS LESS THAN $7 MILLION IN FY 1988-1989: Not Applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-01
Program Element: #62301E
USDR&E Mission Area: 530

Title: Advanced Strategic Concepts and Technical Analysis
Title: Strategic Technology
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The Advanced Strategic Concepts and Technical Analysis Project identifies and evaluates advanced strategic system concepts and system technologies in order to define critical technological issues and establish experimental efforts to provide a basis for defining and evaluating the implications of technology on future weapons systems designs and capabilities. These new initiatives could significantly alter military effectiveness. This project assesses the implications of new technology on strategic policy and conversely the technological implications of new strategic policy, and supports the Under Secretary of Defense for Acquisition (USD-A) and his Director of Defense Research and Engineering (DDR&E) in establishing feasibility and priorities on present and proposed R&D programs. The principal thrusts of this project will be the Strategic Relocatable Target Research program and the Enhanced Lethality/Zero CEP program. Under the Strategic Relocatable Target Research program, research will be undertaken to address new, innovative technologies for reconnaissance and surveillance, with emphasis on space-based concepts, especially radar; signal processing; intelligence fusion; and adaptive strategic planning using knowledge-based systems. Under the Enhanced Lethality/Zero CEP program, new research efforts on potential weapons will be investigated for certain strategic missions. This project also includes studies for DDR&E on bomber modernization issues and bomber force sustainability. It further supports a number of new initiatives including the following: an oxygen extraction (artificial gill) effort to develop the technology to extract dissolved oxygen from sea water and air for underwater power and propulsion, submarine life support, chemical warfare life-support isolation and medical oxygen; RPV's with Non-Acoustic Sensors; a clutter rejection optical pre-processing (CROPP) effort to develop and demonstrate the technology for real time image processing using optical computing technology on the incoming image information as a means to reduce the post focal plane processing burden and achieve extremely high throughput; a counter-terrorism initiative; development of a concept for Space Object Assisted Recovery (SOAR) and other technical analyses of innovative strategic concepts.

2. Program Accomplishments and Future Programs: The project supports the Director of Defense Research and Engineering technically evaluate the technological and capability implications of various policy and treaty provisions. DDR&E has directed studies in bomber modernization issues, strategic air defense penetration and bomber force sustainability. DARPA initiatives include the Strategic Relocatable Target Research, Enhanced Lethality/Zero CEP Weapons, Artificial Gill, CROPP, advanced ECCM technique development, Space Object Assisted Recovery (SOAR), counter-terrorism, and other technical analyses of advanced strategic concepts.

a. FY 1986 Accomplishments: Support for DDR&E continued in evaluating impacts and technology needs for survivability, endurance and effectiveness of strategic forces, with emphasis on modernization of the air breathing leg of

Project: #ST-01
Program Element: #62301E
USDR&E Mission Area: 530

Title: Advanced Strategic Concepts and Technical Analysis
Title: Strategic Technology
Budget Activity: 1. Technology Base

the TRIAD and wartime endurance of strategic forces. A study of emerging technologies to counter strategic relocatable and imprecisely located targets (SRT/ILTs) identified promising concepts and technologies for use during peace and crisis environments. A follow-on effort to extend the analysis was initiated. In the artificial gill project, extraction efficiency from seawater well beyond the energy break-even point was demonstrated. New carrier molecules, analogous to hemoglobin, were developed and synthesized. A preliminary design for an underwater vehicle which uses this technology was prepared. The CROPP program was conceived in FY 1986, and a technology and mission survey were completed. A competition for initial studies was held. Program formulation for the counter-terrorism initiative was accomplished and potential concepts to solve specific problems, such as hostage location, were identified. Significant advances in development of ECCM techniques applicable to space radar systems were achieved.

b. FY 1987 Program: DDR&E support is continuing with emphasis on use of bombers in conventional conflicts. State of the art technologies and system capabilities that might be used to enhance the capability of heavy bombers in the conventional role are being identified and evaluated. Identification and assessment of SRT/ILT technologies and Concepts for Enhanced Lethality/Zero CEP Weapons continue. In the artificial gill project, extraction efficiency is being brought to the point which will enable an underwater vehicle to operate independently using only oxygen extracted from sea water and stored fuel. Final designs for a simple demonstration vehicle are being prepared and fabrication is beginning. In CROPP, five parallel Phase 0 studies are being performed to select a strawman mission, survey the technology and provide candi developed. Studies to identify approaches and techniques for counter-terrorism are being initiated by a working committee within DARPA. Techniques for safe recovery of space objects are under evaluation in SOAR, with emphasis on use of a guided parafoil design. ECCM technique development is being transitioned to the Air Force.

Integrated Non-Acoustic Anti-Submarine Warfare: Flight tests will determine limits of system performance. These results may lead to advanced field testing in FY 1988-89. An experimental program to build and test an airborne system for submarine detection will begin. Initial tests at-sea will occur. A joint UK/US experiment will be conducted and significant studies are planned. Work on advanced radar systems will be started. A high altitude, super pressure platform (balloon) communications transponder program will be started.

c. FY 1988 Program and Basis for FY 1988 Request: Current DDR&E studies on bomber force survivability, endurance and effectiveness in conventional conflicts will be completed. Follow-on studies directed by DDR&E will be initiated. Selected SRT/ILT and Enhanced Lethality/Zero CEP Weapons technologies will be pursued with initiation of validation experiments and component demonstrations. In the artificial gill project an underwater vehicle will be fabricated and demonstrated. New work on carbon-dioxide (exhaust-gas) removal development will begin. Extended life testing of the

process will start. Second-generation, application-oriented demonstrations will be planned. Technology development for CROPP will begin. Development of key pieces of hardware, architectural development and simulation, systems simulation and field measurements as appropriate will be conducted. Major initiatives in counter terrorism will begin in such areas an artificial intelligence applied to passenger and baggage screening at airports, devices to increase lead time for intelligence and warning of terrorist activities, non lethal neutralization of terrorists in hostage situations, and location of terrorists. A flight test program for SOAR components will be initiated.

Integrated Non-Acoustic ASW: The Airborne Blue-Green Laser Radar (LIDAR) will be flown and data will be evaluated. System software will be tested and sea data will be processed. Sea truth instrumentation will be fabricated and tested. Additional sea test plans will be finalized. Non-acoustic sensors will be tested in the Arctic in order to understand the background noise phenomena associated with the (Arctic) environment and to assess the ASW potential of the concepts. The first magnetometer array tests will be conducted. Additional tests of the high altitude communications transponder will be conducted. A major SAR experiment will be conducted. Experiments will be conducted to explore other innovative technologies in this area.

d. FY 1989 Program and Basis for FY 1989 Request: DDR&E directed studies will continue. Demonstration of high payoff technologies for countering the SRT/ILT threat including the application of Enhance Lethality/Zero CEP Weapons will continue in coordination with Service programs. Work will begin on the Service-oriented oxygen extraction demonstrations and experiments. Joint participation with the Army and Navy will have identified the high promise applications of this technology to underwater power and chemical warfare isolation. Life testing of the technology will be completed and assessment of the carbon-dioxide removal process will be conducted. CROPP will continue development of selected effort started in FY88 with downselection based on technical success and results of systems simulation. Progressively greater emphasis will be placed on integrated demonstrations. Counter terrorism efforts initiated in FY88 will continue. Initial assessment of the SOAR concept based on helicopter and/or aircraft drop tests will be conducted.

Integrated Non-Acoustic ASW: The airborne system will continue tests and data analysis. A major Synthetic Aperture Radar and advanced radar experiment will be conducted and earlier results analyzed.

e. Program to Completion: This is a continuing program to identify and perform technical analysis on advanced strategic concepts. Results of analyses, experiments and demonstrations will determine whether concepts are discarded, or carried forward to eventual transition to the Services. The DDR&E studies are a continuing element of this project. The artificial gill project will be completed in FY 1990 with the completion of the joint DARPA and Navy or Army

Project: #ST-01
Program Element: #62301E
USDR&E Mission Area: 530

Title: Advanced Strategic Concepts and Technical Analysis
Title: Strategic Technology
Budget Activity: 1. Technology Base

demonstrations/experiments. SRT/ILT Research and Enhancement Lethality/Zero CEP Weapons Research will continue with development and demonstration of hardware, and integrated demonstration planning and execution, in combination with Service activities. A flight demonstration of CROPP is planned for FY 1991. Counter-terrorism and SOAR initiatives will be transitioned to the Services for full scale development, if and when appropriate.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestone
--	Early FY 1987	Start Oxygen Extraction demonstration vehicle fabrication.
--	Mid FY 1987	Joint US/UK SAR experiment
Early FY 1988	Early FY 1988	Multiple towed tests
Early FY 1988	Early FY 1988	Complete building of LIDAR experiment instrumentation
--	Late FY 1987	CROPP technology and source selection
--	Mid FY 1988	Oxygen Extraction demo vehicle testing
--	Mid FY 1988	CROPP key technology development complete
--	Mid FY 1988	SOAR demonstration design complete
--	Late FY 1989	Counter terrorism technology demonstration
--	Late FY 1989	Application oriented oxygen extraction demonstrations

Project: #ST-01
Program Element: #62301E
USDR&E Mission Area: 530

Title: Advanced Strategic Concepts and Technical Analysis
Title: Strategic Technology
Budget Activity: 1. Technology Base

--	Late FY 1989	SRT/ILT Research Demonstrations
--	Late FY 1989	CROPP component demonstrations
--	Late FY 1989	SOAR Flt test (Air drop)
--	Mid FY 1990	Demonstration of enhanced lethality/zero CEP component technologies
--	Late FY 1990	Oxygen extraction project transitions to Army and Navy
--	Late FY 1991	CROPP flight demonstration

g. Explanation of Milestone Changes: None. Integrated Non-Acoustic Anti-Submarine Warfare (ASW): Completion of integrated ASW has been delayed because of the complexity of the problem, and contractual delays have stretched out the project.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Computing
Title: Strategic Technology
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The objective of the Strategic Computing Program is to develop and demonstrate a new generation machine intelligence technology that can be exploited both to create advanced military systems and to maintain U.S. world leadership in computer technology. The basis for this revolutionary new generation machine intelligence technology are recent advances in artificial intelligence, computer systems, and microelectronics. The main components of the Strategic Computing Program are Military Applications, Technology Base, and Infrastructure. The current Military Applications projects include an Autonomous Land Vehicle (ALV), systems for the Naval Fleet Command Center Battle Management Project (FCCBMP) and for Army Airland Battle Management (ALBM), a Pilot's Associate system, and systems for Radar/Optical Imagery Analysis and for Smart Weapons. The role of the applications projects is to provide a realistic task environment for the creation of an advanced, systems level, Machine Intelligence technology. Also, these projects are designed to serve as the principal means of demonstrating the emerging technology and of transferring it to military systems and to the industrial base. The main research areas in the Technology Base are Machine Intelligence, Machine Architectures, Microelectronics, and DARPA's first mathematics program, the Applied and Computational Mathematics Program (ACMP). The current Machine Intelligence projects are focusing on Vision, Speech, Natural Language Processing, Knowledge Based Systems, and Planning and Intelligent Interfaces. The goals of the research in Machine Intelligence are to attain major advances in the functional capabilities of information processing systems, of the types required in the Military Applications projects. Research on Computer Architectures is being directed to large-scale multiprocessor systems with performance improvements over conventional uniprocessor systems of 2-3 orders of magnitude. Multiprocessor system architectures which are suitable for both symbolic and large scale numeric applications will be developed. Software and design/analysis tools for these very-high performance computers will be developed. The increased computing capabilities expected from the new architectures are intended to provide

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Computing
Title: Strategic Technology
Budget Activity: 1. Technology Base

the real-time performance required by the machine intelligence and other systems. This will lead to the development of a new technology base of scalable modules that will enable the rapid configuration of systems of desired performance characteristics. All of the larger scale architecture prototype projects are performed in cooperation with industry to accelerate technology transition. Very large-scale integrated systems and fabrication technology will be developed to enable rapid prototyping of integrated circuits and multiprocessor systems. The focus of the Applied and Computational Mathematics Program (ACMP) is on solving critical scientific problems in DoD by developing innovative mathematical methods and models in the areas of nonlinear dynamical systems, harmonic analysis, turbulent flow in fluid dynamics, and image/data compression, as well as using advanced computers in innovative ways to enhance research in mathematics. The DoD problems being addressed include: the ability to control and predict turbulence and other kinds of "chaotic" behavior which are important in military vehicle design, (progress in this area will lead to improved design capability for aircraft and submarines; higher data/image compression ratios; and real time calculations of discrete fourier transforms for radar and image processing). The Infrastructure component of the Strategic Computing Program provides network communications to link researchers, access to common computing resources including new multiprocessor architectures, software and systems standards to enable effective transition and to provide a convenient programming environment, and access to an integrated circuit fabrication service for custom designs. Advances derived from the microelectronics research, such as techniques for new wafer-scale integration, and optoelectronic approaches for component interconnection and packaging will provide the enabling technology necessary to implement the new multiprocessors to meet military requirements.

2. Program Accomplishments and Future Programs:

a. FY 1988 Accomplishments: Key Military Applications projects were started. The Autonomous Land Vehicle (ALV) demonstrated computer vision following a controlled road over a range of 4 kilometers at speeds up to 10 kilometers per hour. Knowledge engineering was begun with the Commander-in-Chief, Pacific Fleet (CINCPACFLT) staff for the Force Readiness Expert System (FRESH) designed to monitor changes in Fleet wide readiness. Following a competitive

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Computing
Title: Strategic Technology
Budget Activity: 1. Technology Base

procurement for Pilot's Associate contractor teams, led by Lockheed-Georgia Company and McDonnell Aircraft Company, each began development of the Pilot's Associate system. Simulations by Boeing Airplane Company, General Dynamics Corp., Northrop Corp. and Systran Corp. provided insight into the potential increases in misison effectiveness resulting from the Pilot's Associate. Competitive procurements were initiated for the Army's Airland Battle Management (ALBM) project. Also, in the ALBM program, a working expert system and LISP work station continued upgrade and testing at the Army's 9th Infantry Division. Additionally, an intelligent Maneuver Control System (MCS) trainer prototype using natural language was demonstrated for the Army Training and Doctrine Command (TRADOC). A first-generation prototype for automated exploitation of strategic visual band images of submarine facilities was demonstrated. A program to automatically screen large area Synthetic Aperture Radar (SAR) images for tactical targets was initiated. DARPA's Smart Weapons program was started to spearhead developments in conventional defense by developing the technology base for the next generation of autonomous weapons. Two applications have been identified: (1) an Autonomous Airborne Vehicle (AAV) or "smart bus;" and (2) an Intelligent Munition (IM). The AAV will penetrate deep into enemy territory, search for relocatable and high value targets, and dispense a variety of munitions depending on the decision made using its sensors and onboard computers. The IM will search a small area of the target region, lock on to a target, and attack it. In the Machine Intelligence area, research projects in computer vision, speech, natural language, and knowledge-based systems began to provide new capabilities. For example, in computer vision an initial implementation of the SCVision (Strategic Computing Vision) New Generation System (NGS) was completed at Carnegie-Mellon University (CMU). A number of vision modules capable of detecting and following roads and detecting and avoiding obstacles under a variety of environmental conditions have been incorporated into this NGS. These have been transferred to the ALV project at Martin Marietta in Denver for further evaluation. In speech, a prototype implementation of multiple knowledge sources has been demonstrated; knowledge sources for acoustic phonetic recognition, word hypothesis,and sentence level hypothesization have been constructed. A high performance continuous speech system with 99% word accuracy on a 350-word task was demonstrated for a speaker dependent mode. In the area of natural language, the IRUS

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Computing
Title: Strategic Technology
Budget Activity: 1. Technology Base

system has been demonstrated in the Fleet Command Center Battle Management Program (FCCBMP) at CINCPACFLT (Commander-in-Chief, Pacific Fleet). In Knowledge Based Systems, the ABE system was demonstrated on an air strike replanning task utilizing modular programming capabilities. In addition, the DARPA-Knowledge Engineering Environment (KEE) development system was demonstrated using a robust Assumption Based Truth Maintenance System integrated with a multi-world reasoning system. In the multiprocessor system architecture area, research projects in modeling, simulation, and prototyping of new and innovative scalable signal, symbolic, and multifunction systems have begun to produce medium scale prototypes. The two-cell programmable systolic array prototype (called the WARP processor) was scaled up to 10 processors through a cooperative program with industry. WARP was demonstrated on a variety of problems to have a performance approaching 100 MFlops including low-level vision requirements of an autonomous land vehicle. Design of Very Large-Scale Integrated (VLSI) circuit WARP was started. Advanced software for the Connection Machine, parallel I/O, and mass storage will be developed. The prototype Connection Machine was scaled up from 16 thousand to 64 thousand processors and demonstrated on a variety of problems including low and mid level vision, VLSI design and simulations, hydrodynamics, and massive text search. The tagged-token data flow architecture was emulated. The multiprocessor emulation facility was scaled from 16 to 32 processors and experiments started to support the design of dynamic data flow architectures. A 128 Mbyte VAX system with software was completed as part of the Massive Memory Machine and design of a 1,000 Mbyte system has started. A logic programming accelerator with a performance of 300 thousands of logical inferences per second (KLIPS) was demonstrated with an advanced workstation and the design of a VLSI version started. A prototype for a multiprocessor Ada compiler and run time system was completed. A compact LISP machine chip was fabricated. Prototype development of a desktop LISP multiprocessor was started. The initial prototype of an advanced framework for Common LISP programming environments was completed and experimental use started. Research in the Applied and Computational Mathematics problem was initiated during the first quarter FY 1986. Accomplishments include: development of an algorithm to compute a Discrete Fourier Transform (DFT) that has achieved a ten-fold increase in speed over the Cooley-Tukey algorithm; development of algorithms to meet the DFT requirements

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Titie: Strategic Computing
Titie: Strategic Technology
Budget Activity: 1. Technology Base

for the Radar Image Anaiysis Appiication (ADRIES) which achieved a 30% increase in speed over other algorithms; development of optimized DFTs with improvements in speed ranging from 32% to 70% compared to other aigorithms; deveiopment of theory, algorithms and software for seiected targets, which achieve data compression ratios of 10,000 to one as compared to ratios of 10 to 1 by other methods. In the Infrastructure area, test structures for e-beam programming of wafer scale circuits have been successfuily fabricated and tested. The Metal Oxide Semiconductor Impiementation System (MOSIS) rapid prototyping system for integrated circuits has been repiicated in a secure faciiity to support classified design efforts. This service, known as RMOSIS has had an extremely successfui first year of activity. The LISP machines from various vendors that support the Common LISP standards were procured to support specific research projects. These have been used to expiore appiications in distributed expert systems, machine vision, and high speed combat simuiation. The MOSIS custom chip system was successfully used to test advanced circuit designs using 1.25 micron Compiementary Metal Oxide Semiconductor (CMOS). In the Micro/Opto-Eiectronics area, the coupiing of optical fibers to electronic chips was radicaliy improved by achieving a vertical coupling technique to replace the cumbersome horizontal butt-coupling method previously used. A significant milestone was reached in achieving the monoiithic integration of Gailium Arsenide (GaAs) light-emitting diodes with siiicon (Si) eiectronics, even though GaAs and Si are relatively incompatible materials. This represents a criticai step toward deveioping an optoelectronic technology with reduced size, weight,and power requirements for the massive interconnection requirements of advanced muitiprocessors.

b. FY 1987 Program: In Military Applications, the Autonomous Land Vehicle (ALV) is demonstrating autonomous road foiiowing at speeds up to 20 kilometers per hour (KPH) over various road types with obstacies using the WARP and Butterfly architectures and new generation vision processing algorithms from the Technoiogy Base. The Navy Fleet Command Center Battie Management Project (FCCBMP) Force Readiness Expert System (FRESH) prototype is instaiied and demonstrated at Commander-in-Chief, Pacific Fleet (CINCPACFLT) headquarters aiong with the naturai ianguage interface. Work on the second of five expert systems, the Capabiiities Assessment Expert System

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Computing
Title: Strategic Technology
Budget Activity: 1. Technology Base

(CASES) is started and integrated with the ABE expert system environment. During Phase One of the Pilot's Associate program, the two Pilot's Associate contractor teams are completing functional descriptions of each component expert system to match the operational needs of the pilot and of other avionics systems. Automated exploitation techniques for strategic imagery are being extended to include strategic bomber bases. The first prototype of a Synthetic Aperture Radar (SAR) image screener is being demonstrated. Rapid combat simulations using a multiprocessor architecture are being tested for the first time in the Army Airland Battle Management (ALBM) project. Phase I studies are in progress for the Smart Weapons program. The technical issues being addressed are: interplay between Artificial Intelligence (AI) and standard numerical/signal processing; multi-sensor management and fusion; dynamic mission management; autonomous targeting decisions; and real-time computing hardware. A prototype version of ABE is being delivered to the research community to enable performance evaluation and enhancement. The new generation vision system is being enhanced considerably and is being demonstrated in a new vehicle testbed. Visual competence of the SCVision (Strategic Computing Vision) NGS (New Generation System) is being demonstrated on: cross-country travel and dirt roads; roadway navigation, map guidance, revision, and generation; and piloting capabilities for open-terrain navigation. The integration of various knowledge sources within a speech system framework is underway. A continuous speech system with 200-word vocabulary and an isolated word recognition system which recognizes utterances in the face of high noise and speaker stress are being demonstrated. The JANUS natural language system is evolving from the IRUS system now installed and demonstrated in the Navy Fleet Command Center Battle Management Program (FCCBMP) testbed at Commander-in-Chief, Pacific Fleet (CINCPACFLT). The structure of the new-generation expert system, ABE, is being implemented, and modules for evidential reasoning, explanation, and knowledge acquisition are being incorporated. Intelligent Interface research is concentrating on improving performance between a military operator and machines. In the Multiprocessor System Architecture area, a VLSI implementation for WARP programmable systolic array system is being designed to provide compact high performance numeric accelerators for use with multifunction computer systems. A modular signal processing architecture is being prototyped to provide the performance of hardwired heterogeneous signal

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Computing
Title: Strategic Technology
Budget Activity: 1. Technology Base

processing system with the flexiblity of programmable interconnection. Alternative approaches to developing large-scale shared memory systems are being designed and prototyped. This will provide a performance range of 10 to 10,000 million instructions per second (MIPS). Design of an integrated circuit version of the logic programming accelerator will continue in preparation for fabrication and use as a multiprocessor. A Massive Memory Machine implemented as a 128 Mbytes VAX will be scaled up to a 1,000 Mbyte Sun Server. The Applied and Computational Mathematics Program (ACMP) will address the following objectives: continuing the development of methodologies to describe, predict and control turbulent and chaotic behavior and the nonlinear stability of plasms and fluid dynamics. This will provide improved military vehicle design, drag control and characterization of surface and subsurface wakes. In the Infrastructure program, RMOSIS, the secure Metal Oxide Semiconductor Implementation System (MOSIS), will expand its classified facility vendor base for 1.2 micron circuits, and open the service to a wide range of users. MOSIS is being expanded to include Gallium Arsenide (GaAS). In Microelectronics, research is nearing completion on the development of integrated multiplexer/laser chips and demultiplexer/detector chips, operating at 1 Gbit per sec., for providing high speed data links for the multiprocessor architectures. Fabrication has begun on the optical links for board-to-board interconnection of the 64 thousand processor Connection Machine. Work has begun on the development of both hybrid electronic/optical and all-optical crossbar switches with a 100 MHz bandwidth and a reconfiguration time of 25 microseconds. Research efforts in high density chip packaging technology are being initiated. The overall goal is to demonstrate the feasibility of achieving one billion floating point operations per second (GFLOPS) and four giga-bytes within 100 cubic inches, and implementing it economically by mass production means. The work encompasses both high density memory and generic packaging efforts for logic. Initially very Large-Scale Integrated (VLSI) circuit chips are being interconnected in order to demonstrate the packaging of a 25 megahertz silicon (Si) processor and its associated memory.

c. FY 1988 Planned Program and Basis for FY 1988 Request: In Military Applications, the Autonomous Land Vehicle (ALV) will demonstrate autonomous, cross-country,

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Computing
Title: Strategic Technology
Budget Activity: 1. Technology Base

navigation over rough terrain with speeds up to 10 kilometers per hour (kph). Vision processing, route planning and re-planning will be accomplished along with mission planning using on-board multiprocessors; object classification will use a multi-spectral imaging laser radar. The Force Readiness and Assessment Scheduler for the Naval Fleet Command Center Battle Management Project (FCCBMP) testbed will be demonstrated at CINCPAFLT (Commander-in-Chief, Pacific Fleet) headquarters. The Combat Action Team expert system will be demonstrated on-board the U.S.S. Carl Vinson, CVN-70, during a major fleet exercise. Demonstration Three for the Pilot's Associate, to be conducted in September 1988, will integrate the four expert systems with complete knowledge bases and fully developed interfaces. Multiprocessor based, faster than real-time simulations are demonstrated for course of action evaluation in Airland Battle Management (ALBM). Cooperative maneuver planning between the Corps and Division headquarters which demonstrates interactive plan generation, dynamic plan evaluation on a parallel architecture, and intelligent operation order generation will be developed in the ALBM prototype. Advances in automatic target screening of broad area Synthetic Aperture Radar (SAR) imagery will be demonstrated. A model-based target recognition testbed will be demonstrated with SAR imagery. The Smart Weapons program will continue its Phase II development of algorithms and software. Simulations and field validation experiments will be used to test computer programs for: autonomous target recognition; targeting decisions; dynamic mission management; and navigation using digital maps. Multiprocessor system architectures that support the Technology Base software and system standards will facilitate the transition of new-generation machine intelligence technologies in the applications. The New Generation Vision System will demonstrate the integration of sensory data from range sensors (laser scanner and sonar) and color video cameras. Continuous speech research efforts will develop a 1000-word recognition system that operates in near real-time and is able to support robust speech processing for a speaker over mutliple styles of speech. JANUS will demonstrate a language generation capacity. The new generation of knowledge based system tools will become available for exploitation and will be part of several military application

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Computing
Title: Strategic Technology
Budget Activity: 1. Technology Base

development efforts. New capabillties for knowledge based simulation will emerge. Speech Understanding will be demonstrated ln a Battle Management testbed at Naval Ocean Systems Command (NOSC). Transition of the New Generation Systems (NGS) to multiprocessor system architectures will begin. A medium-scale modular signal processing architecture will be demonstrated. Prototype development of an advanced Connectlon Machine will begin using advanced technologies such as wafer-scale designs. A medlum-scale modular integrated system archltecture for multifunction/symbollc/signal processing will be developed. A medium-scale coarse graln shared memory multiprocessor system will be developed. The Massive Memory Machine prototype system will be available as a network server. A small-scale tagged token dataflow system will be developed. Accelerators for logic programming execution will be designed and fabricated in very Large-Scale Integrated circuit (VLSI). Parallel software synthesis for a variety of multiprocessor system architectures using a knowledge base approach will be developed and demonstrated. The Applied and Computational Mathematics Program (ACMP) will begln new initiatives in dynamical systems, turbulent flow in fluid dynamics, computational algorithms, and control theory. Development of a Mach 20 digital wlnd tunnel, lmpossible to undertake prevlously due to the lack of accurate mathematical models of turbulence and lack of computing power, will be initiated. In the Infrastructure area, the Metal Oxlde Semiconductor Implementation System (MOSIS) will continue to provide fabrication servlces for both silicon (Si) and Gallium Arsenide (GaAs) circuits, as well as printed circuit boards for use in prototyping new system architectures. The RMOSIS system will provide similar services for highly classified applications. In the Opto-Electronics area, a wldeband optoelectronic 16 by 16 crossbar switch will be delivered to DARPA for use in one of the heterogeneous multiprocessors. GaAs and Si circults will be fabricated on sapphire substrates to provide a monollthic optoelectronic capability for silicon integrated circuits. The optical interconnect of VLSI chips through free-space will be demonstrated. High density packaging efforts will continue. The generic interconnection approaches will be modified so as to demonstrate the packaging of a silicon processor and lts associated memory running at speeds of 40 megahertz. The high density memory interconnect scheme will be optlmized and scaled up, and

work started on the fabrication and assembly of a sufficient number of modules to demonstrate the four giga-byte goal.

d. FY 1989 Planned Program and Basis for FY 1989 Request: Autonomous Land Vehicle's (ALV) integrated system will plan and execute a 5 kilometer long path to a forward deployment position. The path may include road networks and rough country terrain. Development of a combat analysis expert system will be completed allowing force-on-force comparisons to be made and it will be integrated into the Commander-in-Chief, Pacific Fleet (CINCPACFLT) testbed. Phase Two of the Pilot's Associate program, a two-year effort beginning in FY 1989, will produce a real-time demonstration in the contractor's full mission simulator, using Service fighter pilots. Advanced computer hardware and software from the Strategic Computing technology base will be utilized to achieve performance goals. The Strategic Image Exploitation (SIE) testbed will be transfered to an operational facility for demonstration and technology evaluation. The technoiogy base for automated screening of broad area Synthetic Aperture Radar (SAR) imagery will be transitioned to advanced parallel architectures. The model-based target recognition testbed will be extended to include Inverse Synthetic Aperture Radar (ISAR) imagery. In the Smart Weapons Program, Phase II software products will be integrated and tested in simulations and/or field experiments. In the Machine Intelligence area, the New Generation Vision System will be demonstrating upgraded capabilities based on the integration of motion detection modules, terrain modeling modules, sensor fusion processes using the blackboard, and all running as an integrated system. The New Generation System (NGS) will demonstrate its capabilities by executing a complex mapping mission, including on and off road segments which approximates the reconnaissance tasks of a forward military scout. Continuous speech systems that integrate natural language processing techniques will begin to be integrated into the Navy and Army Battle Management and Pilot's Associate applications to provide speech understanding capabilities in operational situations. Cooperating knowledge based systems with near real time performance will be utilized in various applications. In natural language technology, the JANUS

system will begin transition into the Navy Fleet Command Center Battle Management Project (FCCBMP) testbed. In text understanding, PROTEUS-II will provide robust processing of typical Casualty Report (CASREP) messages; producing database/knowledge updates on status of equipment failures. Knowlege Based Systems (KBS) will take a new focus of using the developed tools and environments to concentrate on complex problem solving. Intelligent Interface research will focus on modeling the application designer and the operational user. In the architectures area, the basic scalable multiprocessor modules designs and prototypes will be demonstrated. This will provide the basis for achieving an additional 3 orders of magnitude in performance. The Applied and Computational Mathematics Program (ACMP) will continue the new initiatives that will be started in FY 1988. The image/data compression effort will complete development of algorithms and software for the exact compression and regeneration of digitized grey tone two-dimensional images, and the corresponding specifications for the design of a machine to achieve real time compression and regeneration of real world digitized images delivered. In Infrastructure, wafer-scale designs fabricated through the MOSIS prototyping service will demonstrate the capability to integrate the equivalent of tens of millions of transistors in a single 4" by 4" silicon substrate. In the Micro-Electronics areas, a wideband opto-electronic 32 x 32 crossbar switch will be demonstrated. The utility of optical interconnects in multiprocessor architectures will be shown upon replacement of 12,288 wires with just 24 fibers in the Connection Machine. The packaging of a 200 MHz Gallium Arsenide (GaAs) processor will begin using government-supplied GaAs chips. Multiple high density memory modulus will be interconnected to begin the demonstration that the goal of 4 giga-bytes can be achieved.

e. Program to Completion: Current applications projects will be concluded and the systems level technologies developed will be transferred into military systems. The Autonomous Land Vehicle (ALV) will progress to full autonomy. In FY 1990, the ALV will plan and execute routes using a 50-meter grid terrain data base, instead of the specialized five-meter grid data base; after the ALV has navigated to an obstacle's location, incoming vehicles will be detected and reported. In FY 1992, the program will be completed by demonstrating technologies which show

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Computing
Title: Strategic Technology
Budget Activity: 1. Technology Base

the feasibility of developing unmanned, robotic, combat vehicles, which are capable of defending an obstacle placed in the path of on-coming armor. For the Fleet Command Center Battle Management Program (FCCBMP), the program will conclude with the development of an integrated C2 system in 1990 which incorporates fleet readiness, capabilities assessment, operations planning, and strategy generation and evaluation. For the Pilot's Associate, Phase Two of the program will conclude at the end of FY 1990 with Demonstration Four, a real-time, full mission simulation. Image analysis application projects will continue into FY 1991 during which automated target screening for synthetic aperture radar imagery will be demonstrated in an operational environment and a multi-sensor target recognition testbed will be completed. For the Airland Battle Management program (ALBM), the central developmental effort reaches full, planned, concept demonstration in FY 1991. For the Smart Weapons program, the test and evaluation of Phase II products will be completed in FY 1989. Contractors will proceed in a Phase III demonstration program with a flight program in FY 1992. Both the Autonomous Airborne Vehicle (AAV) with its Intelligent Avionics Suite (IAS) and the Intelligent Munition (IM) will proceed to Phase III. New military applications will be focused to take advantage of the opportunities provided by increasingly more advanced Strategic Computing Program technologies. Candidates include Strategic Air Command (SAC) targeting/retargeting, new-generation "intelligent" seekers for fire-and-forget weapons, automation of high-cost weapons production lines, location of fleeting, or imprecisely located, targets, and logistics resupply. Strategic Computing Vision (SCVision) research results in the form of algorithms with their properties and various vision subsystems used for static and dynamic scene recognition will be produced and disseminated to support work on many other military application systems, as well as to strengthen the national technology base in computer vision. The major thrusts in Strategic Computing (SC) natural language technology which are to develop two new generation systems - the JANUS system for a natural language interface and the PROTEUS system for text understanding will each evolve over time and provide increased functionality to users. Very large stores of generic and task specific knowledge will form the basis for distributed knowledge bases that will become a valuable national asset. Refined tools and environments for developing and using Knowledge Based Systems (KBS) on parallel architectures will be readily available in the

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Computing
Title: Strategic Technology
Budget Activity: 1. Technology Base

community to support advanced research and development and to support real time processing of complex operational applications. The research efforts of the Applied and Computational Mathematics Program (ACMP), (through FY89) will provide the following technologies to satisfy DoD requirements: engineering tools to improve design capabilities for hypersonic and highly manueverable aircraft; a Digital Wind Tunnel to alleviate shortcomings of wind tunnel testing; improved interpretation of oceanic surface signatures; a software system for high speed exact image/data compression and regeneration, with compression ratios of 10,000 to one (whereas current techniques only yield 10 to 1). Powerful new technologies will be available which will allow the integration of the equivalent of tens of millions of transistors on a single 4" x 4" silicon substrate. The homogeneous scalable multiprocessors will be used as an extensible base to develop heterogeneous systems with extensible object-oriented software. Advanced system software will be developed for the new generation of scalable computing modules that will provide a three to four order of magnitude increase in system performance. Software and system development technology will be developed to support the effective use of heterogeneous parallel systems. This will lead to the development of a rapid prototyping capability for parallel systems and serve as a prototype for a new industrial base. The developing technology base for optical interconnections is forming the foundation for optical crossbar switches and intracomputer networks. The crossbar switches will be used in the heterogeneous systems while the optical networks will be used in the homogeneous scalable multiprocessors. The small, high density conventional packaging program will demonstrate a high density signal processing function in a volume that is appropriate to a smart weapon configuration.

f. Milestones: FY 1988 milestones which were listed in last year's report and have been accomplished are not shown below.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Title: Strategic Computing
Title: Strategic Technology
Budget Activity: 1. Technology Base

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Last Year's Reported Plan	Current Plan	Milestone
Early FY 1987	Early FY 1987	Compact Lisp machine for military use demonstrates 10 times the performance of larger conventional Lisp processor.
Mid FY 1987	Mid FY 1987	Innovative multi-processor architectures demonstrated with speed potential of 1000 times conventional architectures with comparable technology speeds.
- -	Late FY 1987	Demonstrate open country off road navigation with the Autonomous Land Vehicle (ALV).
- -	Mid FY 1987	Combat Action Team expert system demonstrated on U.S.S. Carl Vinson, CVN-70.
- -	Mid FY 1987	Demonstrate Capabilities Assessment Expert System (CASES) full system architecture at the Naval Fleet Command Center Battle Management Project (FCCBMP) testbed.
- -	Mid FY 1987	Submarine Base Vision expert system demonstration.
Late FY 1987	Late FY 1987	Demonstrate cooperating maneuver planning expert system moves at Corps level for Airland Battle Management (ALBM).

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Title: Strategic Computing
Title: Strategic Technology
Budget Activity: 1. Technology Base

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Last Year's Reported Plan	Current Plan	Milestone
Late FY 1987	Late FY 1987	Demonstrate prototype of software planning system tool, STAR 1, for ALBM knowledge-based systems.
Late FY 1987	Early FY 1989	Photorefractive beam scanning demonstration.
- -	Late FY 1987	Demonstrate JANUS (Natural Language follow-on to IRUS) at FCCBMP testbed.
- -	Late FY 1987	Demonstrate Mach operating system on medium scale multiprocessors.
- -	Early FY 1988	Demonstrate JANUS-I, natural language interface, in selected context of Naval battle management and force/equipment readiness.
- -	Early FY 1988	Demonstrate screening of Synthetic Aperture Imagery for tactical targets.
- -	Early FY 1988	Strategic bomber base vision expert system demonstration.
- -	Mid FY 1988	Demonstrate PROTEUS-II robust processing of selected message text producing knowledge base updates.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Title: Strategic Computing
Title: Strategic Technology
Budget Activity: 1. Technology Base

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Last Year's Reported Plan	Current Plan	Milestone
- -	Late FY 1988	Demonstrate Autonomous Land Vehicle (ALV) speed of 10 kilometers per hour (KPH) over rough terrain.
- -	Late FY 1988	Demonstration of monolithic integration of Gallium Arsenide (GaAs) laser diode and a silicon (SI) device.
- -	Early FY 1989	Demonstrate New Generation System (NGS) Vision system upgraded with motion detection, terrain modeling, sensor fusion, and all running as an integrated system.
- -	Late FY 1989	Demonstration of high density packaging with 40 megahertz silicon processor.
- -	Early FY 1989	Demonstration of optical links in the Connection Machine.
- -	Early FY 1989	Demonstrate a 5,000 word continuous speech recognition system.
- -	Mid FY 1989	Demonstrate JANUS-II, natural language interface, in select context of battle management.
- -	Mid FY 1989	Overhead image analysis system using artificial intelligence and supercomputers installed in an intelligence operational environment.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Title: Strategic Computing
Title: Strategic Technology
Budget Activity: 1. Technology Base

Project: # ST-10
Program Element: #62301E
USDR&E Mission Area: 530

Last Year's Reported Plan	Current Plan	Milestone
- -	Mid FY 1989	Delivery of a 32 x 32 wideband optical crossbar switch.
- -	Late FY 1989	Demonstrate 1,000 MIP shared memory systems.
- -	Late FY 1989	Demonstrate 1,000 MIP Distributed memory systems.
- -	Late FY 1989	Demonstrate 1,000 MFLOP memory systems.
- -	Late FY 1990	Demonstrate New Generation System (NGS) Vision system running on a heterogeneous machine while performing navigation tasks in a dynamically changing environment.
- -	Mid FY 1992	Flight/Demonstration of autonomous capabilities of Autonomous Airborne Vehicle (AAV), Intelligence Avionics Suite (IAS) and Intelligent Munitions (IM).

g. Explanation of Milestone Changes: Delays due to contract negotiation.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-11
Program Element: #62301E
USDR&E Mission Area: 530

Title: Intelligent Systems
Title: Strategic Technology
Budget Activity: 1 Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The Intelligent Systems project is investigating fundamentally new capabilities for intelligent information processing including support for the software and systems design process. This will enable computers to assist, advise, and/or relieve military personnel in complex decision-making tasks, including those related to systems development and maintenance and in tasks which are tedious, dangerous, or rapidly changing. The project investigates fundamental science and technology that promise exciting new intelligent information processing capabilities. The DARPA Strategic Computing Program (ST-10) is based on the foundation laid by years of basic research performed under the Intelligent Systems program. It was launched to capitalize on promising developments in the Intelligent Systems program, and to accelerate machine intelligence technology to a point of significant impact on Defense systems and on the national industry. The specific approach continues to be fundamental research at the frontiers of artificial intelligence (AI) and computer systems. As specific areas and technologies show strong promise for further exploitation and large-scale development, they will be transferred to other DARPA programs such as the Strategic Computing Program. The objections of this program will be to continue to demonstrate revolutionary new machine reasoning capabilities and new opportunities for the rapid prototyping of next-generation software systems for Defense needs which are flexible, robust, and cost effective. Research pushes at the boundaries of machine intelligence in developing computational equivalents for human cognition, perception, and action. Research efforts focus on creation of new automated reasoning processes; invention of new knowledge representation frameworks and knowledge acquisition tools to support these representations; enhancement of image understanding; demonstration of intelligent user interfaces; conception of protocols that promote cooperative problem solving among autonomous agents in distributed environments; demonstration of software architectures for knowledge-based systems; inventions in machine learning aimed toward automating the system maintenance and improvement process; investigation of the intelligent organization and management of knowledge bases; and development of new software for parallel processing. Techniques for shared access to very large knowledge bases and databases will be developed with a focus on high performance robust systems. A

Project: #ST-11
Program Element: #62301E
USDR&E Mission Area: 530

Title: Intelligent Systems
Title: Strategic Technology
Budget Activity: 1 Technology Base

new generation of software and systems development environments based on machine intelligence technology is being developed to accelerate software productivity and the system production process.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: The knowledge-based image understanding system, called SPAM, when applied to the task of photo-interpretation of airport images from satellite data, demonstrated the use of spatial and structural constraint knowledge of airports to generate and rank order multiple plausible scene models. This new approach to image understanding integrates rule-based systems, spatial databases from the Defense Mapping Agency, and a collection of feature-specific image analysis modules. Algorithm improvements for image understanding continue to increase the efficiency of feature extraction and matching processes (e.g. linear feature extraction, region segmentation using color and texture, line matching, image to map matching, etc.). For example, an improved algorithm for visual stereo was developed that runs about two orders of magnitude faster than previous algorithms on conventional LISP machines. In the area of natural language processing, a control structure for supporting expert systems with flexible explanation facilities was developed. Explanation and knowledge representation enhancements needed for a prototype demonstration system were completed, as well as development of explanation strategies for six of 13 query types. Also in natural language research, an initial computational model of discourse structures, which can be used to extend the robustness of natural language interfaces in dealing with phenomena such as referring expressions and interruptions in dialogue was developed. A text- understanding system, RESEARCHER, that accepts technical texts, organizes the information in a dynamic memory, and answers queries about the dynamic knowledge base has formed the basis of work that has been provided to researchers at the Federal Bureau of Investigation (FBI) Academy. Hitech, an intelligent searching machine implemented in an innovative parallel architecture specialized for the game of chess, won the North American Computer Chess Championship and scored the highest rating ever achieved in machine/human competition. A knowledge-based editor, KBEmacs, was demonstrated as part of the programmer's apprentice project and assisted in automatic program construction of several 50-100 line programs. As part of a machine learning project designated the World Modelers, a prototype of the Prodigy learning

architecture was developed, as well as a prototype of the Fermi system, which models the discovery process in the natural sciences. Version 4.0 of the prototype machine learning and problem-solving architecture, SOAR, was demonstrated and released for use by other DARPA researchers. A new method of learning rules by automated experimentation with a qualitative model was demonstrated to require about 30 times less memory space and contained about 10 times fewer rules than a comparable knowledge base constructed by hand. Control structures which have significant problem domain knowledge were developed for supporting expert systems with flexible explanation facilities. A prototype system for automatic load balancing and reconfiguration of a distributed sensor network was completed. A knowledge-based system for interpreting three-dimensional signal information was demonstrated using a blackboard control structure. A new approach to integrated programming environments, Formal Software Development (FSD), based on a persistent object base, was designed and a prototype developed. A prototype functional programming language, ROSE, with formal semantics to support machine intelligence assisted verification of specific formal properties was designed, the initial prototype developed, and evaluation started. A prototype inferential programming model was developed.

b. FY 1987 Program: Research focuses on improving image understanding theory and practice, basic schemes for automated problem solving and machine learning, knowledge-based software tools, prototype demonstrations of Defense applications of AI, and distributed machine intelligence. In image understanding, work continues on developing new computational methods for inferring surface and shape information of objects by exploiting explicit knowledge contained in color, texture, and motion models. Building on a production-rule foundation, a knowledge-based image understanding system framework is being developed that integrates high and low level vision. This framework allows total system experimentation combining new low-level image feature analysis techniques with other feature specific sources of knowledge. Work continues on techniques for automatically acquiring 3-D object recognition algorithms from CAD-type shape descriptions and example images for future practical applications, e.g., hand-eye coordination in recognizing a desired part among other randomly placed parts in a bin-picking system. The use of parallel algorithms are being explored to improve the efficiency of image understanding and to gain a better understanding of new multi-processor hardware

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-11
Program Element: #62301E
USDR&E Mission Area: 530

Title: Intelligent Systems
Title: Strategic Technology
Budget Activity: 1. Technology Base

now becoming available in other DARPA programs. Analysis of various classes of knowledge-based systems continues on how different tasks (e.g., data fusion tasks such as the CAT system on board the USS Carl Vinson) can be decomposed into parallel processes for implementation on different multi-processors. Current machine perception systems, built using sensor-specific algorithms and dependencies, are expensive and difficult to extend to newer sensors. Hence, basic research has begun to create generic, logical sensor models within an object-oriented paradigm. The first experiments illustrate the ideas of a separable interface between the sensor's data and the processes that use the data and are for simple classes of tactile and vision sensors in a robotic assembly testbed. The machine learning, Software Architecture (SOAR) continues as a testbed for various research tasks. SOAR is being focused next on designing computer algoithms and automatically synthesizing executable programs from the design. The prototype Learning Apprentice system (LEAP), which learns by observation, is being demonstrated on design tasks by observing human designers in the domain of very Large Scale Integrated (VLSI) circuit design. LEAP demonstrates the ability to produce implementation rules from specific training examples acquired from students taking a VLSI design course. The experimental text understanding and intelligent retrieval system, RESEARCHER, is being extended to form a system for processing and organizing information in text samples from tank maintenance manuals. A system for generation of database management modules is being demonstrated with the focus on very high performance processing. A new class of shared knowledge management systems is being developed for spatial and temporal data management and recursive query facilities. An expert system that utilizes an explanation process which is relatively easy to modify and extend is being designed. A resource management program that guides preparation of management plans for resource allocation using knowledge base technology is being implemented. An empirical analysis of a distributed problem solving system is being conducted to better understand high-level distributed control for fault-diagnosis, load balancing, and organization. A new software and systems evaluation environment is being designed and extended to support multiple developers. The ROSE system is being evaluated

experimentally and will be extended to support reasoning about the official DoD computer language, Ada. Designs for a new software design environment are being started.

c. FY 1988 Planned Program and Basis for FY 1988 Request: In image understanding, methods for estimating motion from "noisy" data will be demonstrated in an experimental mobile robot. At least one program will be demonstrated which is robust enough to distinguish regular man-made texture patterns from indoor scenes as well as outdoor city scenes. Demonstrations of improved recognition capabilities for robotic bin-picking will be accomplished based on automatically acquired, 3-D recognition algorithms. Improvements in speed, accuracy, and robustness of certain image understanding algorithms will be demonstrated. Enhancements will be integrated into production rule-based frameworks. Integration of multiple sensor models into testbeds will be accomplished by incorporating range, force/torque, and motion-tracking models. The learning apprentice system, LEAP, will have its knowledge extended to infer control rules as well as implementation rules from observation of Very Large Scale Integrated Circuits (VLSI) circuit designers. The SOAR problem solving and learning architecture will demonstrate automatic creation of a new problem space (i.e., to create data representations and operators for a new problem). A new approach to building powerful and adaptive problem solving systems based on the case-based reasoning paradigm will be initially demonstrated in a military task domain. Case-based reasoning systems will be explored to prove the theoretical advantages expected by building automated problem solvers which employ their own past experiences to recognize and plan for new ones. Research in expert systems will focus on creating a parallel version of an existing knowledge-based system to measure the gains due to the parallel decomposition of a problem. Separate modules, usable in many applications, will be developed for inference, control, and representation. This development will provide intelligent tools to guide users in building expert systems. Systems that effectively couple the flexibility of intelligent systems with the principled structure and efficiency of database systems will be developed and applied to military problems, e.g., map interpretation, resource management, and design and manufacturing processes. A generic distributed problem-solving architecture that includes the control and data flow relationships among the meta-level control components will be developed. A new

Project: #ST-11
Program Element: #62301E
USDR&E Mission Area: 530

Title: Intelligent Systems
Title: Strategic Technology
Budget Activity: 1 Technology Base

subsystems for object management, knowledge representation, reasoning, transformation, specifications, and user interfaces. The system will be used to develop medium scale examples involving multiple developers. A prototype reasoning environment for a subset of Ada will be available for experimental use. Prototype development of a software design environment will be started from competitive selections.

d. FY 1989 Planned Program and Basis for FY 1989 Request: In image understanding, the VISIONS system, a complex large-scale AI testbed for integrating low, intermediate, and high level visual operations on complex images of either natural scenes, as might be needed for photo interpretation tasks, or indoor scenes, as might needed for industrial robotics tasks, is expected to achieve initial operational capability on a specialized "pyramid" parallel architecture. Using the VISIONS testbed, several important issues in integrated machine perception and cognition will be explored: 1) focus of attention, so that only the relevant sensory data need be processed; 2) complex control strategies, to orchestrate the operations chosen for the images; 3) inferencing under uncertainty, choosing visual operations with unreliable, inconsistent, and incomplete data and hypotheses; 4) perceptual organization, allowing symbolic tokens to be more easily matched to stored-object schemas; 5) information fusion, bringing together in a single coherent representation the data from multiple sensors, representations, and knowledge sources; and 6) automated knowledge acquisition, permitting perceptual systems to expand over time automatically. New theories of reflectance and color differences will enable programs to determine surface reflectance and color in spite of unknown illumination. New theories will be needed for stereo matching and other vision techniques to use in dynamic environments. The automatic generation of vision recognition algorithms will be demonstrated as a learning procedure within the SOAR paradigm. SOAR, Prodigy and case-based problem solving paradigms will each be tasked to demonstrate their adaptive problem solving performance on some task that would be judged difficult by human standards and not possible with

current standard knowledge-based systems technology. A new software design environment prototype will be available for initial experimental use.

e. Program to Completion. The basic research program in artificial intelligence will continue to explore perception and cognition problems whose solution could revolutionize DoD systems in the future. Certain capabilities at the bounds of AI technology, e.g., common sense reasoning, machine learning, and image understanding, will find limited military application, e.g., targeting systems, command and control systems, and automatic target recognizers. The most promising specific techniques will be explored in large scale testbed systems in other DARPA projects, e.g. the Strategic Computing program (ST-10). Knowledge acquisition, knowledge management, knowledge representation, and machine learning will continue to be critical in applying artificial intelligence to Defense systems. Work will continue in cooperative problem solving, reasoning with uncertainty, image understanding knowledge-based system tool development, and natural language because of their overwhelming importance in solving critical military problems. Additionally, research on problem-solving in large, complex systems will focus on identifying key issues that depend on problem complexity and that require further invention and exploration. Research in planning and user modeling will be exploited in command and control systems. Research to develop methods for computers to discover knowledge and learn new rules will enable development of more robust, flexible, and cost effective systems. The structure and formalism of database technology will be merged with the powerful representation and control models used in artificial intelligence in order to produce knowledge management methods that efficiently support complex query processing and sharing of information among distributed processors. Discoveries in automated learning and discovery methods will produce significant advances in planning systems. Knowledge base representation advances will result in better query optimization methods for data access and in improved methods to represent goals used for planning systems. Research will focus on those fundamental problems in intelligent data management important to large, distributed command and control systems. Ways will be found to effectively meld the benefits of flexible representations and reasoning abilities of knowledge-based systems with the structure and efficiency of database systems. New experimental environments will be developed to support the development of new software and process models. Knowledge representation,

Project: #ST-11
Program Element: #62301E
USDR&E Mission Area: 530

Title: Intelligent Systems
Title: Strategic Technology
Budget Activity: 1 Technology Base

acquisition, and reuse techniques will be developed to support knowledge-based rapid prototyping, production quality refinement, and evaluation. Strategic computing technology will be inserted using the new architectures for advanced distributed systems to increase functionality and performance.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestone
Mid FY 1987	Mid FY 1987	Demonstrate SOAR's ability to do algorithm design and program synthesis from that design.
- -	Mid FY 1987	Demonstrate initial capability to classify the appearance of 3-D objects based on range and intensity imagery.
- -	Mid FY 1987	Demonstrate color edge-detectors, color correlation operators, and the automatic removal of color image highlights.
Mid FY 1987	Mid FY 1987	Demonstrate the dimensional information handling and knowledge processing capabilities of an advanced data management system.
Mid FY 1987	Mid FY 1987	Demonstration of a system for generating programs in a specific domain from high-level specifications.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Title: Intelligent Systems
Title: Strategic Technology
Budget Activity: 1 Technology Base

Project: #ST-11
Program Element: #62301E
USDR&E Mission Area: 530

Last Year's Reported Plan	Current Plan	Milestone
- -	Mid FY 1987	LEAP will demonstrate the ability to learn and produce VLSI implementation rules by observing the actions of human designers.
- -	Late FY 1987	Demonstrate RESEARCHER processing 20 paragraph length text examples taken from tank maintenance manuals.
Late FY 1987	Late FY 1987	Demonstrate the blackboard control architecture to implement control reasoning.
Late FY 1988		Demonstrate that SOAR is capable of creating a new problem space.
- -	Late FY 1988	Demonstrate a mobile robot capable of estimating the motion of targets from noisy data.
- -	Late FY 1988	Demonstrate automatically-acquired 3-D recognition algorithms for enhancement of robot capability to do bin-picking behaviors.
- -	Late FY 1988	Demonstrate the RESEARCHER based system processing over 100 text samples from tank maintenance manuals and using additional learning and generation components.
- - -	Late FY 1988	Demonstrate a prototype adaptive automated problem solver using case-based reasoning.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-11
Program Element: #62301E
USDR&E Mission Area: 530

Title: Intelligent Systems
Title: Strategic Technology
Budget Activity: 1 Technology Base

Last Year's Reported Plan	Current Plan	Milestone
- -	Late FY 1988	Create a parallel version of an existing knowledge-based system and provide measures of the gains due to the parallel decomposition.
- -	Late FY 1988	Prototype new experimental environment applied to new process models.
- -	Late FY 1988	Demonstrate the explanation capability of a blackboard system that includes meta-level reasoning.
- -	Late FY 1988	Complete benchmarks of a multi-user high performance database machine.
- -	Late FY 1988	Demonstrate a knowledge management system with condition monitoring, real-time update, and time constrained processing.
- -	Late FY 1988	Demonstrate formal reasoning support for a verifiable subset of Ada.
- -	Late FY 1989	Demonstrate the VISIONS system.
- -	Late FY 1989	Complete a color difference measure theory.
- -	Late FY 1989	Demonstrate the generation of vision recognition algorithms within the SOAR paradigm.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-11
Program Element: #62301E
USDR&E Mission Area: 530

Title: Intelligent Systems
Title: Strategic Technology
Budget Activity: 1 Technology Base

Last Year's Reported Plan	Current Plan	Milestone
- -	Late FY 1989	Compare the SOAR, Prodigy, and case-based reasoning paradigms performance on various tasks.
- -	Late FY 1989	Demonstrate experimental parallel versions of knowledge-based systems in at least two task classes.
- -	Late FY 1989	Demonstrate enhanced capabilities of replanning explanations to produce clarifying information.
- -	Late FY 1989	Demonstrate a prototype software design environment.

g. Explanation of Milestone Changes: None.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-12
Program Element: 62301E
UDR&E Mission Area: 530

Title: Advanced Quantum Electro-Optics
Title: Strategic Technology
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The objective of the Advanced Quantum Electro-Optics project is to develop optical technologies to make possible a broad range of new military capabilities. This project, started in late FY 1985, focuses on developing advanced materials and techniques for increasing the spatial resolution of optical systems, increasing the temporal resolution of optical and microwave systems. This includes work on non-linear optics for real time holography and sensor protection; advanced adaptive optics for atmospheric correction, for imaging or matched-filter target detection; and picosecond laser technology for precision measurements of material processes and ultrafast optoelectronics.

Technology developments under the Strategic Defense Initiative Organization (SDIO) are periodically reviewed to identify possible opportunities for exploitation as well as possible areas of neglect as SDIO focuses on its mission and cuts back on directed energy technology development.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: Laboratory experiments were designed and assembled to confirm the computer codes and analysis. Data collection and analysis were underway.

An integration of experimental hardware to be used in the Short Wavelength Adaptive Techniques (SWAT) II program during FY 1987-88 was accomplished and demonstrated. A revised program plan to reflect several new avenues of approach was required and subsequently formulated.

Progress was made in developing non-linear optics technology. New materials were developed for efficient harmonic generation to produce new laser wavelengths. Improved understanding was obtained of the performance capabilities and limitations of the four-wave mixing technique as well as the charge controlled large-array deformable mirror.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-12
Program Element: 62301E
UDR&E Mission Area: 530

Title: Advanced Quantum Electro-Optics
Title: Strategic Technology
Budget Activity: 1. Technology Base

b. FY 1987 Program: Starting in FY 1987 and for the next several years, this project focuses on the development of unconventional atmospheric compensation technology, non-linear optics technology and novel short wavelength lasers. The development of these high risk technologies have potential high payoffs in ground-based laser ASAT, as well as battlefield tactical military capabilities.

There are two aspects to the unconventional atmospheric compensation technology program. The first is to establish the scientific techniques and a broad technical base in atmospheric compensation technology to permit an informed evaluation of the different approaches.

The objective of the second aspect of the unconventional atmospheric compensation technology program is to develop concepts and technologies for affordable, ground based optical imaging.

Achieving high resolution imagery of space objects from the ground, working in the visible, require (1) concepts which compensate for or are insensitive to the effect of atmospheric turbulence and (2) concepts which provide a large effective aperture that either do not require much optical quality or that can make use of sparse array pattern of light collectors. A number of new technical options have recently appeared in astronomy journals and in proposals to DARPA, which seem to offer practical ways around these difficulties. In FY 1987, the different options and concepts are being evaluated, and competitive designs to demonstrate the most promising concepts are expected to start.

The objective of the multi-year effort in materials science and non-linear optics technology development is to establish the technology base that would support a variety of potential military applications. In FY 1987, this includes continuing work on developing crystalline materials for efficient harmonic conversion of laser output to generate new wavelengths in the visible and in the mid-infrared; developing new materials for four-wave mixing phase conjugation and new work on advanced phase conjugation techniques to relax optical and mechanical tolerances in laser design. In addition, this program will develop improvement in laser operational reliability and compactness; extend laser brightness improvement to high output energies; develop practical devices which operate at low laser power for automatic target tracking; produce novel countermeasure concepts against anti-sensor lasers; and demonstrate coherent beam combining of diode laser arrays.

Project: ISST-12
Program Element: 62301E
UDR&E Mission Area: 530

Title: Advanced Quantum Electro-Optics
Title: Strategic Technology
Budget Activity: 1. Technology Base

c. FY 1988 Planned Program and Basis for FY 1988 Request: In FY 1988, the programs described in FY 1987 will continue. A series of field experiments will be conducted to evaluate the performance of different techniques for the first time. This project will bear the full financial burden of these field experiments and the technology development because SDIO assistance will end.

The Multiple Aperture Geosynchronous Imaging Capability (MAGIC) program, competitive design concepts for proof-of-principle experiments to demonstrate focal plane speckle imaging will be evaluated. One or more of the concepts will be selected for detailed design, fabrication, assembly and installation at an existing facility where it is expected that the basic concept will require minor modifications of a conventional and existing telescope, new sensitive receivers to collect short exposure white-light speckle patterns (which come from sunlight scattered by the target) and computer power to construct an image from the Fourier modulus data. The 1.6m diameter telescope at Air Force Maui Optical Station (AMOS) will be used to collect experimental data from low earth orbit satellites. The array of six 1.8m diameter telescopes forming a baseline of about 7m (the Multiple Mirror Telescope, MMT) at the University of Arizona's Steward Observatory will be used to collect experimental data from satellites. Data collection and analyses will begin in FY 1989.

In the MAGIC program, competitive design concepts for proof-of-principle experiments to demonstrate aperture-plane speckle imaging will be started. The design analysis tasks will produce a set of requirements for the laser illuminator. The laser requirements will be compiled, analyzed, and a set of specifications will be generated which will best fit all concepts. Competition for the laser procurement will be started.

The development of novel materials and nonlinear optics technology will continue. Laboratory demonstrations of advanced phase conjugation will be completed. New materials research that will be started include laser-hardened infrared focal plane array (which take advantage of the controllability afforded by molecular beam epitaxy), novel quantum-well optoelectronic structures (which take advantage of a new generation of metallic organic chemical vapor deposition reactor with laser-assisted processing capability) and novel optical switching materials (which sense and rapidly divert laser radiation to assure safe sensor operation).

Project: IST-12
Program Element: 62301E
UDR&E Mission Area: 530

Title: Advanced Quantum Electro-Optics
Title: Strategic Technology
Budget Activity: 1. Technology Base

d. FY 1989 Planned Program and Basis for FY 1989 Requests: In FY 1989, the programs described in FY 1987 will continue.

The Multiple Aperture Geosynchronous Imaging Capability (MAGIC) program, data will be collected and analyzed to evaluate the performance of the Focal Plane Speckle Imaging technique. If those proof-of-principle experiments are successful, additional data collection time will be scheduled. This will enable the exploitation and use of this concept and technology as a residual operating capability at the AMOS test site.

In the Multiple Aperture Geosynchronous Imaging Capability (MAGIC) program, one or more of the aperture plane speckle imaging concepts will be selected for detailed design, fabrication and functional test. The illumination laser, separately procured, will be fabricated and checked out. All the equipment will be installed and integrated at an existing facility (e.g., AMOS) in FY 1990.

The first phase of the material science and non-linear optics technology development will be completed. Examples of improved and/or novel quantum electro-optical devices will be developed and tested to show improved phase conjugation performance, fast-acting optical switches and laser-hardened electro-optical sensors.

e. Program to Completion: This is a continuing effort. Nonlinear optical materials and self-activating switch materials will be incorporated as appropriate to assure that surveillance and imaging sensors will operate under laser threat irradiance. These technologies will then be transitioned to the military services for further development.

f. Milestones:

g. Explanation of Milestone Changes: No change.

I. TEST AND EVALUATION DATA: Not Applicable.

J. COOPERATIVE AGREEMENTS: Not Applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-13
Program Element: #62310E
USDR&E Mission Area: 530

Title: Strategic Aircraft and Cruise Missile Defense
Title: Strategic Technology
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The Strategic Aircraft and Cruise Missile Defense (SACM) program is DARPA's response to the Air Defense Initiative (ADI). The objectives of SACM are to identify and develop new optimal techniques for surveillance and engagement of aircraft and cruise missiles. Mission functions addressed include surveillance (acquisition, track, identification), targeting and kill assessment. The SACM Program will develop system concepts, associated technologies, and an architecture to provide the building blocks for advanced strategic surveillance capability. The goal is to achieve improvements compared to existing surveillance systems.

2. Program Accomplishments and Future Programs: The SACM program originated from a DARPA sponsored surveillance architecture accomplished in-house with other government agency support. This effort reviewed all the major advanced surveillance technologies that could support future surveillance system needs. The primary targets addressed by SACM extend the President's Strategic Defense Initiative (SDI) for a U.S. defensive shield against ballistic missiles to cover the air breathing threats. The program will evaluate advanced surveillance concepts and platforms and how to integrate them into a robust, highly capable air defense system. Promising concepts and technologies will be selected for further development and associated measurements and demonstrations.

a. FY 1986 Accomplishments: Studies of new innovative techniques and system concepts continued toward selection of the most promising techniques for further technology and concept development. Concepts were evaluated using architectural mission models, and trade-offs were made to evaluate the effectiveness of strawman integrated networks to achieve significantly improved surveillance capability. A demonstration and measurement test program was developed to support a Hybrid Bistatic Radar (HBR) system phenomenology evaluation. Models for infrared and radar sensors were updated. A fusion experiment was defined to establish general procedures for fusing dissimilar sensors. This involves the collection of simultaneous sets of infrared imagery and pulse doppler data on targets and backgrounds as well as associated ground truth data. Discussions were held with the Air Force and OSD to insure that Air Defense Initiative related elements within SACM are fully integrated with and responsive to other ADI programs.

b. FY 1987 Program: Investigation of innovative techniques and system concepts selected for further technology and concept development in FY 1986 are continuing. Initial results from the demonstration and measurement test portion of the HBR program are being documented and analyzed. Updated comprehensive models for infrared and radar sensors will be distributed and plans completed to integrate those models into a single multiphenomenology model to support system architecture development and fusion experiments. Data from the first fusion experiment will be collected and used to

Project: #ST-13
Program Element: #62301E
USDR&F Mission Area: 530

Title: Strategic Air and Cruise Missile Defense
Title: Strategic Technology
Budget Activity: 1. Technology Base

refine algorithms which demonstrate how infrared (IR) and radar sensors can be used in a complementary manner to enhance probability of detection. This data will also establish design principles for optimal configuration of IR and radar sensors, demonstrate the statistical independence of background clutter distributions observed by different sensors, and provide the basis for further multisensor fusion experiments with emerging unconventional detection techniques. A framework for transitioning promising enabling technologies to the Air Defense Initiative (ADI) is being established.

c. FY 1988 Planned Program and Basis for FY 1988 Request: Evaluation of SACM selected concepts and techniques will continue. Validation experiments and demonstrations of the most promising sensor concepts will be initiated. Further fusion experiments will be initiated involving a combination of traditional and unconventional detection techniques including validation of data fusion algorithms. SACM architectural and system studies will continue as results of laboratory experiments, fusion experiments, sensor modelling, and component developments provide new data with which to refine and expand baseline architectural models and system concepts. The baseline SACM threat will be reviewed and updated as required based on current intelligence assessments, weapons developments, policy and strategy. Program structure and goals will be reviewed with the Air Force and OSD to ensure full coordination and consistency with the Air Defense Initiative.

d. FY 1989 Planned Program and Basis for FY 1989 Request: SACM architectural and system studies will be completed. System design issues will be addressed and significant investment in brass boarding of sensor component technologies will be made. Major demonstrations and experiments will be conducted in support of multisensor fusion. Data will be collected on stressing targets against various backgrounds from multiple platforms and subsequently analyzed to evaluate the performance and potential of SACM sensors, both as individual sensors and as elements of an integrated sensor suite.

e. Program to Completion: An advanced surveillance sensors architecture will be developed. Emerging high risk, innovative surveillance technologies will be developed and tested. Maturing technology will be transitioned to the Air Force to support system developments for improved Air Defense. This is a continuing program.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestones
Late FY 1986	Late FY 1987	Initial SACM concept evaluation

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #ST-13
Program Element: #62301E
USDR&E Mission Area: 530

Title: Strategic Air and Cruise Missile Defense
Title: Strategic Technology
Budget Activity: 1. Technology Base

Late FY 1987	HBR radar cross section and clutter measurements
Late FY 1987	Initial fusion experiment
Mid FY 1988	Initiate concept validation experiments and demonstrations
Late FY 1989	Major demonstrations and fusion experiments
FY 1990-93	Incremental transition of concepts and technologies to ADI.

g. Explanation of Milestone Changes: Budget reductions, competitive procurement activities, and reprioritization of SACM efforts resulted in program stretch out and restructuring.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62702E
USDR&E Mission Area: 530

Title: Tactical Technology
Budget Activity: 1. Technology Base

A. RESOURCES: ($ in Thousands)

Project Number	Title	FY 1986 Actual	FY 1987 Estimate	FY 1988 Estimate	FY 1989 Estimate	Additional to Completion	Total Estimated Costs
	*TOTAL FOR PROGRAM ELEMENT	88,552	93,429	114,536	142,551	Continuing	N/A
TT-3	Naval Warfare	22,442	16,217	20,855	30,900	Continuing	N/A
TT-4	Armored Warfare Technology	14,174	34,816	36,846	42,694	Continuing	N/A
TT-5	Target Acquisition and Weapons Technology	33,656	31,336	39,085	47,477	Continuing	N/A
TT-6	Tactical Directed Energy Technology	3,819	6,120	10,750	14,480	Continuing	N/A

*Totals include classified projects not identified herein.

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This program element in FY 1988 and FY 1989 is dedicated to the advancement of research and development of concepts and technologies directed toward the development of the next generation tactical systems. The goal is to advance non-nuclear, tactical, combat capabilities to counter the expanding tactical threat. The major development objectives are: (1) to improve target acquisition and weapons technology; (2) to progress armor/anti-armor technology; (3) to enhance ocean surveillance and anti-submarine warfare targeting and control technolgies; (4) to advance compact moderate-power frequency-agile.

C. COMPARISON WITH FY 1987 DESCRIPTIVE SUMMARY: The total funding for FY 1987 is $17.57 million less than the amount requested for in the FY 1987 Descriptive Summary. This reduction is the effect of the following: (1) a decrement in the Autonomous Infrared Sensor Technology, Millimeter Wave Autonomous Sensor, Air Defense Technology, Hemispherical Resmant Gyro, Advanced Ramjet Technology, and Infrared Binary Optics programs; (2) a transfer and decrease of the Acoustic Charge Transport (ACT) funding from TT-5 to Program Element 61101E reported under Project ES-01.

The above reductions were offset by increases in the Armor/Anti-Armor program, Electromagnetic Gun program and the Anti-submarine Naval Warfare program.

D. OTHER APPROPRIATION FUNDS: None.

E. RELATED ACTIVITIES: Overall coordination of efforts is maintained with representatives of the Under Secretary of Defense for Acquisition USD(A), the offices of the service assistant secretaries responsible for research and advanced development, and the corresponding service headquarters staff offices. In addition, direct coordination of activities with appropriate service laboratories is maintained through means such as technical interchange meetings and conferences.

Specific Naval Warfare project coordination mechanisms are as follows: The Systolic Array Processor program has transferred to the Space and Naval Warfare Systems Command (SPAWAR) and the Naval Sea Systems Command (NAVSEA). Similarly, the ARIADNE Program has also transferred to SPAWAR. The Advanced Conformal Submarine Acoustic Sensor program is being pursued as a joint venture by DARPA, the Office of Naval Research, and the Office of the Chief of Naval Operations (Submarine Warfare) and an existing Memorandum of Agreement (MOA) governs the effort. The Mini-GPS Receiver Program is coordinated with the Global Positioning System Special Project Office and the United States Marine Corps. Project Jade is coordinated with the Chief of Naval Operations (CNO) and SPAWAR.

The Armored Warfare Technology project activities are coordinated with the Army Armament Research and Development Center, Army Ballistic Research Laboratory, Army Materials Technology Laboratory, Naval Surface Weapons Center (White Oak), and Naval Surface Weapons Center (Dahlgren). The Armor/Anti-Armor program is being run by an Executive Steering Committee and a joint program office with representatives from the Army, Marine Corp and DARPA.

In the Target Acquisition and Weapons Technology project, the Surveillance Radar program is a joint development with the Army with which the Marine Corps maintains a close liaison. The Autonomous Infrared Sensor Technology program and the Millimeter Wave Sensor program are coordinated within the three services through the Joint Deputies for Laboratories and under the auspices of the Advanced Target Recognizer Working Group. The Uncooled Sensor program is jointly funded with the Army Vision and Electro-optical Laboratory. DARPA is also an active member of the DoD Anti-Armor Master Plan Steering Group and Working Group. The Small Unit Technology (SUT) program is fully coordinated with Office of the Secretary of Defense/Command, Control, Communications Intelligence/Special Operations Special Technology Program (OSD/C^3 I/SOSTP), with the Joint Special Operations Agency (JSOA) and with the Services. Several of the projects under SUT, e.g., Advanced Technology Tactical Transport (AT^3) aircraft, are jointly funded. The Tactical Use of National Technical Means. (TACNAT) program is jointly funded by OSD/C^3I, Army Space Program Office (ASPO), and Defense Support Program

Office (DSPO) and is fully coordinated with Army and Air Force Anti-Tactical Ballistic Missile (ATBM) activities. The Smart Weapons program is jointly funded with the Air Force Avionics Laboratory, WPAFB; and closely coordinated through the Army and Air Force.

Plans for the new Tactical Directed Energy Technology project are coordinated through frequent technical interchange meetings with representatives from the three Services' tactical directed energy programs. Technology developments under the Strategic Defense Initiative Organization are periodically reviewed to identify possible opportunities for exploitation.

F. WORK PERFORMED BY: Approximately 80% of the work of the Naval Warfare project is carried out by industry and 20% by DoD in-house agencies. Industrial contractors involved in research programs under this project are: Bolt, Beranek and Newman, Inc., Arlington, Virginia and Cambridge, Massachusetts; AMRON Corporation, Fairfax, Virginia; General Dynamics Corporation, San Diego, California; Tetra-Tech Inc., Arlington, Virginia and Pasadena, California; Rockwell International, Anaheim, California; and Magnavox Corporation, Torrance, California; General Electric Company, Syracuse, New York; Raytheon Company, Portsmouth, Rhode Island; Westinghouse Corporation, Annapolis, Maryland; Applied Physics Laboratory, Johns Hopkins University, Adelphi, Maryland.

The in-house effort is performed by the Naval Ocean Systems Center, San Diego, California; the Naval Underwater Systems Center, New London, Connecticut and Newport, Rhode Island; the Naval Ship Research and Development Center, Carderock and Annapolis, Maryland; the Naval Research Laboratory, Washington, D.C.; and the Office of Naval Research, Washington, D.C.

80% of the Armored Warfare Technology project and Target Acquisition and Weapons Technology project work is performed by industry, 15% was performed by a Federal Contract Research and Development Center, while universities account for 5%; the remaining is performed in-house by government laboratories. The performers are the University of Florida, Gainesville, Florida; University of Massachusetts, Amherst, Massachusetts; Purdue University, West Layfette, Indiana; Systems Planning Corporation, Arlington, Virginia; Rockwell International Corporation, Los Angeles, California; Massachusetts Institute of Technology Lincoln Laboratory, Cambridge, Massachusetts; the Environmental Research Institute of Michigan (ERIM), Ann Arbor, Michigan; Martin Marietta Corporation, Orlando, Florida; Westinghouse Corporation, Baltimore, Maryland; Goodyear Aerospace, Litchfield Park, Arizona; University of California, Lawrence Livermore National Laboratory, Livermore California; University of Texas, Austin, Texas; Battelle Institute, Columbus, Ohio; Interactive ITV, Arlington, Virginia; CACI, Arlington, Virginia; Perceptronics, Woodland Hills, California; Scaled Composites, Mojave, California; Honeywell, Bloomington, Minnesota; Boeing Aircraft Co., Seattle, Washington; Science Applications Inc., La Jolla, California; Chemical Systems Division of United Technologies, San Jose, California; BDM Corporation,

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #TT-3
Program Element: #62702E
USDR&E Mission Area: 530

Title: Naval Warfare
Title: Tactical Technology
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestones
Mini-Global Positioning Satellite (GPS) Receiver:		
Mid FY 1986	Mid FY 1987	Complete brassboard
N/A	Mid FY 1987	Initiate Munitions experiment
Integrated Acoustic Anti-Submarine Warfare:		
N/A	Mid FY 1988	Surveillance work station demonstration

g. Explanation of Milestone Changes: Advanced Conformal Submarine Acoustic Sonar (ACSAS): Funding shortfalls and manufacturing delays have stretched out the project.

Mini-Global Positioning Satellite (GPS) Receiver: Delays were encountered because of high risk and uncertainties associated with design, development and foundry manufacturing of the monolithic microwave integrated circuits.

I. Test and Evaluation Data: Not applicable.

J. Cooperative Agreements: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #TT-04
Program Element: #62702E
USDR&E Mission Area: 530

Title: Armored Warfare Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: This program has been initiated in response to guidance from the Defense Science Board and the Secretary of Defense, and is a key element in providing an enhanced national capability in armor/anti-armor technologies and applications. The overall program objective is to provide significantly increased levels of protection and survivability to existing and future combat systems, and to provide significantly increased lethality and effectiveness to existing and future anti-armor munitions. In the Joint DARPA, Army, and Marine Corps Armor/Anti-Armor program, this will be achieved through the formation of industrial/university "blue teams" which will compete toward a common goal in cyclic development efforts culminated by "shoot-offs" at a central evaluation activity. The winning contractors will be given a task to develop their technology for a specific application, such as armor for a Bradley vehicle or a warhead for an anti-tank missile, in a related program (see EE-21: the Armor/Anti-Armor Advanced Development Project). After updating the goals and guidelines, the proof-of-principle development competition will be reinitiated to achieve higher levels of performance.

The Armor/Anti-Armor program consists of seven major sub-areas, as follows:

a. Armor - The objective of this effort is the development and testing of cost effective armor systems intended for light and heavy combat vehicles to provide significantly improved protection and reduced weight. These armors will include all appropriate technologies. Competing systems will be tested using advanced Soviet-style threats and evaluated using an algorithm reflecting the best current estimates of performance and operational trade-offs. Successful concepts will be transitioned to application programs.

b. Vehicle Survivability - The objective of this effort is to develop a system for combat vehicles which will minimize the effectiveness of an incoming threat munition. Competing approaches will be tested using threats. This system will operate in conjunction with the advanced armors described above for existing and future light and heavy combat vehicles.

c. Chemical Energy Warheads - The objective of this effort is the design and testing of chemical energy (shaped charge, explosively formed projectile) warheads. These developments will be applicable to existing (retrofit) and future medium and heavy direct-fire, elevated attack, and over-flight systems, and to tank-fired ordnance.

d. Kinetic Energy Penetrators - The objective of this effort is the development of advanced projectiles providing increased effectiveness including accuracy, efficiency of penetration, and lethality over current projectiles. The initial focus of this effort is a parametric examination of the penetration mechanics for a variety of projectile and armor types at velocities from one to five kilometers per second. Based on these results, novel penetrators will be developed by competing teams. These results will be applicable to penetrators for gun-launched, missile-borne, and electromagnetic gun systems.

e. Integrated Weapons and Platforms - The objective of this effort is to develop concepts and systems for armored

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #TT-04
Program Element: #62702E
USDR&E Mission Area: 530

Title: Armored Warfare Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

concepts; the Independent Management Activity located at Los Alamos National Laboratory is p[illegible]eding toward specific technology development goals and is preparing for the initial round of shoot-offs and evalua[illegible]ns; and the Red Design Bureau is engaged in intelligence and technology assessment. Overviews of these programs follow.

Four armor team contractors are competing in the following areas: two teams pursuing both light and heavy armors, one pursuing light armor only, and one pursuing heavy armor only. These armors will be evaluated at a shoot-off. Unofficial intermediate in-house shoot-offs will be used to demonstrate subsystems and to provide short-term spin-offs for specific appli[illegible]ations.

The vehicle survivability program has four competing teams pursuing development of proof-of-principle systems.

In the chemical energy warhead program, four industrial teams are competing to defeat projected Soviet heavy armors. In addition, Lawrence Livermore National Laboratory is providing support in the areas of explosives research and novel warhead concepts. Full scale firings of the High Explosive Anti-Tank Rifle (HEAR) grenade will be performed, and the results evaluated to determine its future status.

The kinetic energy projectiles program is quantifying the penetration of various penetrator options through four experimental programs. This will lead to the formation of competitive design teams. Advanced ramjet technology efforts include preliminary testing of RAMROD projectiles fired from a tank gun. Experimental and modeling efforts are scheduled. This program will then transfer to the Army.

The Integrated Weapons and Platforms Program involves two efforts: a study team of four contractors examining the concepts, issues, and programmatics of an advanced family of combat vehicles, and a mine/countermine effort which is performing technology development and is examining mine detection options. The Distributed Explosive Charge with Afterburning (DECA) mine neutralization technology is undergoing instrumented testing to determine its suitability for further development.

The Independent Management Activity is preparing test plans for all upcoming shoot-offs, is setting up test facilities and equipment, and is preparing to host a number of meetings to acquaint the user community with its basic research function and results. Standardized penetration models are being prepared for use in armor and penetrator design work, and materials development and characterization is proceeding for a number of ceramic and composite armor materials and for shaped charge liners.

The Red Design Bureau is examining intelligence and open-source information to determine threat system designs.

Major efforts in the Electromagnetic Gun Technology Demonstration program will be for the completion of the hypervelocity test ranges and commencement of projectile development tests and completion of detailed design of the repetitive fire systems. Concept designs for guided hypervelocity projectiles and fire control systems will be completed.

Project: 3TT-04
Program Element: 3627028
USDR&E Mission Area: 530

Title: Armored Warfare Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

c. FY 1988 Planned Program and Basis for 1988 Request: The program plan for FY 1988 includes continued development of all "blue team" efforts, the initial shoot-offs, continued general research at the Independent Management Activity, hardware deliverables and continued assessment by the Red Design Bureau. In addition, concepts which can contribute significantly to achieving the Armor/Anti-Armor Program goals will be supported in areas where "blue teams" have not already been formed (or are not appropriate) until such time as these concepts can be incorporated or organized into a competitive team.

Several shoot-offs and concept evaluations will occurduring this time. Evaluations will be made of all systems by the IMA. These will result in the initiation of an application program (see EE-21: Armor/Anti-Armor Advanced Development Program) to provide prototype systems for use in a specific weapon or vehicle such as a new warhead for a Tube-launched, Optically-tracked, Wire-guided (TOW) missile, all around anti-tank missile protection for a Bradley, or a new armor system for the Light Armored Vehicle (LAV). The competitions will then be reinitiated with updated and more stringent threats and conditions. Reinitiation of the vehicle survivability competition may not be necessary.

The kinetic energy penetrator teams will conduct internal testing during this period, but are scheduled for formal shoot-offs. Research will continue to develop penetrators with increased accuracy and efficiency, with particular focus on candidates suitable for 105 and 120 mm tank guns. The advanced ramjet program results will be incorporated into this program. Any high value immediate applications of any of the above research will be pursued vigorously without regard to shoot-off schedule.

The Integrated Weapon and Platform effort will continue efforts in the areas of advanced combat vehicles and mine/countermine, along with any other efforts requiring a system approach. The advanced combat vehicle effort will include completion of phase I vehicle design concepts, formulation of required operational capabilities statements, testing of critical technologies for data links, sensor systems, and vehicle construction techniques, and ordering of long lead-time items for subsystem testing. Efforts in the mine/countermine area will include further development link for wide area mines and exploration of concepts for remote mine/explosive detection. Work on Distributed Explosive Charge with Afterburning (DECA) will be transitioned to the Army.

Major efforts in the Electromagnetic Gun Technology Demonstration program will focus on continued range tests of the two single shot laboratory guns, construction of the repetitive fire gun systems and on component development for guided hypervelocity projectiles.

d. FY 1989 Planned Program and Basis for FY 1989 Request: The general program plan for FY 1989 is similar to that for FY 1988 with two exceptions: some systems will have entered the related advanced development program (EE-21) and will be altered or deleted from this program, and emphasis will shift toward development of integrated systems in the Integrated Weapons and Platforms project. It is also likely that new efforts will be initiated in areas not yet covered under the current plan.

Project: ITT-04
Program Element: 62702E
USDR&E Mission Area: 530

Title: Armored Warfare Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

Shoot-offs will occur in the kinetic energy penetrator program, with transition to advanced development (e.g. an improved penet chemical energy warhead programs, with modified goals.

The Integrated Weapons and Platforms Program will be conducting sub-system tests in preparation for an advanced combat vehicle testbed. Proof of principle demonstrations and a mine detection system are anticipated during this period. It is likely that a new program such as a tank gun system upgrade could also be initiated during this period.

The Electromagnetic Gun Technology Demonstration program will conduct comparative test firings of the completed repetitive-fire gun systems. Final designs for the second phase prototype gun systems will be evaluated. A decision to proceed to prototype construction and preparations to transition the program to the Army will be made.

e. Program to Completion: This is a continuing project, however, individual areas will be completed through transition to advanced development, transition to the Services, or cancellation due to lack of progress or the perception that no further work is needed. It is anticipated that each area described previously (armor, vehicle survivability, chemical energ warheads, kinetic energy penetrators, and integrated weapons and platforms) will result in at least one specific system application. In areas such as armor and anti-armor warheads, it is anticipated that the competitive process will proceed through a number of cycles, each culminated by a shoot-off and each resulting in a specific system application. The vehicle survivability program will culminate in a system with continuing research as needed to improve its cost effectiveness or scope of application. The electromagnetic gun will transition to the Army with possible continued DARPA involvement in requirements of launchers and guided projectiles.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestones
Armor/Anti-Armor Program:		
Late FY 1986	Late FY 1987	High Explosive Anti-Tank Rifle (HEATR) grenade demonstrated.
Late FY 1987	Late FY 1987	Distributed Explosive Charge with Afterburning and HEATR will transition to the Services.
Late FY 1986	Continuing	Identify mechanisms and phenomenology of advanced armor; characterization of equation-of-state materials at high strain rates; develop advanced

Project: #TT-04
Program Element: #62702E
USDR&E Mission Area: 530

Title: Armored Warfare Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestones
		materials at high strain rates; develop advanced passive and active armor techniques.
Early FY 1989	Early FY 1988	Test of lightweight applique for light armor vehicles.
Electromagnetic Gun Technology Demonstration Program		
--	Late FY 1987	Single shot 9 megajoule electromagnetic (EM) gun test start. Begin construction of (3) repetitive fire testbeds.
--	Mid FY 1988	Hypervelocity anti-armor projectile tests start.
--	Mid FY 1989	Repetitive fire integrated EM gun system tests.
--	Late FY 1989	Prototype design selection. Decision to build.
--	Early FY 1990	Transition to Army.
--	Late FY 1991	Prototype EM weapon system demonstration.

g. Explanation of Milestone Changes:

The Advanced Armor Technology program, the Advanced Warhead Technology program, and the Advanced Ramjet Munitions program were consolidated into the Armor/Anti-Armor program to achieve coordinated goals and approaches.

The Penetration Augmented Munition and Bridge, Road, and Tunnel programs were cancelled due to combined effects of the Gramm-Rudman Act and undistributed Congressional cuts.

The Adaptive Warhead program was superseded by elements of the Armor/Anti-Armor program.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #TT-04
Program Element: #62702E
USDR&E Mission Area: 530

Title: Armored Warfare Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

The Electromagnetic Gun Technology Demonstration program was moved to TT-04 from TT-05 to achieve closer coordination of program goals with those of the Armor/Anti-Armor program.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: TT-05
Program Element: 62702E
USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

B. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The Target Acquisition and Weapons Technology project (TT-05) is designed to help offset expected enemy numerical advantages in deployed weapons and systems through increasing the lethality and effectiveness of U.S. fielded systems. The project concentrates on those technologies and applications with potential major force multiplication advantages.

The Tactical Use of National Technical Means program is developing techniques to increase the utility of national technical means to tactical commanders by: partially automating intelligence preparation of the battlefield processes to reduce area search; conducting analyses to build behavior rules and developing a garrison indications and warning methodology.

Sensor and algorithm technologies for fire-and-forget munitions and other highly specialized applications are being developed in several related programs: the Autonomous Infrared (IR) Sensor Technology, the Uncooled IR Sensor Arrays, the Millimeter Wave (MMW) Autonomous Sensor, and the Infrared Binary Optics programs. The Autonomous IR Sensor Technology program is structured to provide a technology base for future IR seekers and sensors associated with air-to-ground tactical operations such as advanced anti-armor missiles, terminal homing projectiles and attack helicopter target acquisition sensors. A government standard image database and image evaluation standards will be developed with which to gauge the performance of advanced algorithms and perform comparison of sensor techniques including Carbon Dioxide laser radar and passive IR imaging. The program is jointly managed and funded by DARPA and the Army, with active participation from the Air Force and Navy. The Uncooled IR Sensor Arrays program is developing two-dimensional imaging arrays of ferroelectric, pyroelectric and other room temperature techniques for sensing 8-12 micron IR energy. Current photoconductive and photovoltaic 8-12 micron sensors (such as the Tube-launched, Optically-tracked, Wire-guided (TOW) Night Sight require cryogenic cooling (down to 77°k or lower); this cooling imposes severe weight, cost, size and power penalties on tactical sensors. A primary application for uncooled IR imaging is in potentially low cost high production volume sensors such as missile seekers and projectiles. The MMW Autonomous Sensor program is developing the technology base for a new generation of precision-guided weapon seekers and forward area surveillance and target acquisition radars capable of high performance in adverse weather. The development of a multi-mode, fully polarimetric, high resolution airborne instrumentation radar has provided the capability to gather a robust imagery database. With this database, the Millimeter Wave (MMW) program is stimulating the evolution of radar and Automatic Target Recognition (ATR) algorithms and technologies. The Autonomous MMW and Infrared (IR) Sensor Technology programs together are providing the technology base required to adequately address multi-sensor approaches to reconnaissance, surveillance and target acquisition. The Infrared Binary Optics program is using new developments in holographic grating theory coupled with standard integrated circuit fabrication technology to produce low cost, lightweight holographic optics for IR systems. The program has two major goals: (1) demonstrating the feasibility and practicability of a low cost lightweight IR, lightweight telescope and (2) an all-holographic modular Carbon Dioxide (CO_2) laser radar. This combination of techniques promises to reduce the cost of IR optics by an order of magnitude and infrared system weight by 30%.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: TT-05
Program Element: #62702E
USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

The Small Unit Technology program is exploring advanced technologies and methodologies that address functional areas, such as training, intelligence, command and control, and planning requirements of small units in all the Services. The effectiveness of small units throughout the spectrum of conflict is increasingly recognized; the objective of this program is to increase significantly the probability of small unit mission success through the application of advanced methodolcgies and technology to the referenced functional areas.

The Tactical Military Research and Development planning program assists in the identification and assignment of future priorities.

DARPA's Smart Weapons program is spearheading developments in conventional defense by developing the technology base for the next generation of autonomous weapons. Two applications have been identified: an Autonomous Airborne Vehicle (AAV) or "smart bus"; and an Intelligent Munition (IM). The AAV will penetrate deep into enemy territory, search for relocatable and high value target, and dispose a variety of munitions depending on decisions arrived at using its sensors and onboard computers. The IM will search a small area of the target region, lock on to a target, and attack it. The activity in this project is related to the efforts begun in FY 1986 under Strategic Computing (ST-10) and develops a demonstration intelligent munition beginning in FY 1988.

Advanced Ramjet Munition Technology Program was transferred in FY 1987 to TT-04 where it has been combined with the Armor/Anti-Armor program. The Air Defense Technology program which consisted of technology developments for advanced air defense concepts has been zeroed in FY 1987 and outyears. The Electromagnetic Gun Program which was just beginning in the FY 1987 Descriptive Summary has been transferred to TT-04 due to its close alliance with the Armor/Anti-Armor program.

In cooperation with the Rome Air Development Center, the Tactical Expert Mission Planner (TEMPLAR) project, within the Air Land Battle Management (ALBM) program of Strategic Computing, applies the techniques of knowledge-based ("expert") systems to the development of a tactical Air Force air tasking order (ATO).

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: The Tactical Use of National Technical Means program demonstrated partly automated techniques to reduce search area through the use of rules concerning Soviet doctrine combined with semi-automated terrain, weather and vehicle characteristics analysis.

In the Surveillance Radar program, the design and development of hardware and software for the miniaturized Remotely Piloted Vehicle radar was completed and integration of the components begun.

In the Autonomous Infrared (IR) Sensor program, contractors have exercised their target detection and recognition algorithms against the standard data base consisting of several hundred calibrated infrared images. A set of performance metrics have

been tested at the Environmental Research Institute of Michigan. Initial results indicate that it is now possible to objectively compare performance of algorithms and determine if inconsistencies exist between expectations and measured performance. Development continued on the generation and validation of synthetic infrared images to augment and replace field data. The first feature set has been extracted from the multi-dimensional IR database collected by MIT Lincoln Laboratory. This feature set is rich in independent signatures that should provide a robust target classification and recognition capability in the presence of countermeasures and camouflage. Collection and dissemination of the multi-dimensional data is continuing, with emphasis on surface-to-surface missiles to support the Smart Weapons Program in Strategic Computing.

In the Uncooled IR Sensor Arrays program, the first imagery was obtained with a non-pyroelectric technique. The uncompensated array achieved 0.5°C sensitivity. Improvements continued in pyroelectric arrays. Low noise digital readouts for pyroelectric arrays were fabricated and tested prior to mating to lithium tantalate detectors. Solicitations were issued for a High Density Array Development (HIDAD) at the U.S. Army Center for Night Vision and Electro-Optics and an uncooled seeker for anti-ship guided bombs. As a direct result of this DARPA technology, the U.S. Army initiated an advanced development program for an uncooled night sight for an infantry rifle.

The Infrared Binary Optics program was initiated with in-house experiments at MIT Lincoln Laboratory. The technology efforts were aimed at two primary applications: wide-band low cost optics for passive infrared images, and modular fire control/sensor systems for short range air defense, anti-tank, and remotely piloted vehicles. Experiments have shown the ability to coherently add laser modules to achieve higher beam power at visible wavelengths, 3-5 microns, and 8-10 microns. The preliminary design concepts for a low cost infrared telescope were completed, and a strategy for the development was established. Finally, the feasibility of a continuously tunable electron-activated laser employing binary grating optics was investigated. Initial predictions call for efficiencies of 50% or higher with low energy electron beams of 70 K Electron Volts (KEV).

In the Millimeter Wave (MMW) Autonomous Sensor program, research on MMW tactical target detection/ classification techniques continued. Alternative discrimination algorithms were examined and optimized and several new algorithms discovered. Design and fabrication of a MMW airborne radar testbed was continued. Contracts for development of new target detection/classification algorithms were awarded.

Small Unit Technology program: Accomplishments included completion and operational evaluation of a concept demonstrator of a swimmer delivery vehicle (SDV) part-task trainer, initiation of a small arms special weapons trainer, and continuation of a 62% scale prototype of an all composite Advanced Technology Tactical Transport. The SDV is a vehicle used by Naval Special Operations personnel. Defense Advanced Research Projects Agency (DARPA) developed a computerized training system to enable training of the operators in a much more cost effective fashion. Unlike a full-scale environmental simulator, a part-task trainer is a low cost, effective way to train critical system skills. The Swimmer Delivery Vehicle trainer is oriented toward pilot and navigator skills as well as mission rehearsal and planning. Wind tunnel tests of the Advanced Technology Tactical Transport's wing section broke the Ohio State University record for coefficient of lift.

Project: TT-05
Program Element: #62702E
USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

The Tactical Expert Mission Planner (TEMPLAR) work has begun. TEMPLAR/Air Land Battle Management (ALBM) interface planning is underway.

b. FY 1987 Program: In the Tactical Use of National Technical Means program, tactical ballistic missile trafficability feature extraction techniques development continues. Analysis for and rule implementation of tactical ballistic missile templates is being expanded. Exploitation algorithm development is continuing and demonstrations are being planned in coordination with the Army.

In the Surveillance Radar program, integration of the miniaturized Remotely Piloted Vehicle (RPV) Surveillance Radar is being completed, captive flight tests with the radar and RPV fuselage attached to a manned aircraft are scheduled, and free flight demonstrations aboard a remotely piloted vehicle are planned but not currently funded due to undistributed funding cuts. The Army is actively participating in the program and transfer of the technology is pending Army funds.

In the Autonomous Infrared (IR) Sensor program, multi-dimensional infrared imagery is being collected; the imagery consists of passive infrared, laser radar, and laser doppler images which are registered pixel by pixel. The combination of target features in the various sensor domains is being evaluated as a tool in autonomous classification in the presence of countermeasures and camouflage. The imagery is being delivered to algorithm developers and Smart Weapons contractors for use in evaluating target detection and classification software. Metrics for evaluating algorithm performance are being used to determine levels of performance achievable by various types of target detectors, image segmentors and classifiers. A database is being generated documenting results of algorithm evaluation. Synthetic imagery is being generated and compared with real imagery in a series of validation experiments.

In the Uncooled IR Sensor Arrays program, contracts are being awarded for the development of high density arrays. This High Density Array Development (HIDAD), will result in arrays of small pixels. Concepts for uncooled arrays that can achieve this density are being investigated. Bolometers and pyroelectric detector arrays are being tested in prototype image structures. Pyroelectric arrays with potential for high density are also in development. A lock-on after launch seeker for anti-ship bombs is in development. The seeker uses an array of pyroelectric detectors and is jointly funded with Naval Air Systems Command.

In the Infrared (IR) Binary Optics program, MIT Lincoln Laboratory is continuing to pursue two tactical applications: low-cost optics for passive IR imagers, and modular fire control. The program is structured to achieve industry participation by a competitive award of a three year contract to pursue one of the primary applications. This contract will parallel in-house coope.ative efforts at MIT Lincoln Laboratory. Work is continuing on coherent laser beam addition, extending the technique to short wavelengths (ultraviolet). Other optical components for modular fire control are being tested: scanners, filters, lenses, and telescopes. A benchmark wideband optical telescope for use on passive imagers is being fabricated. The design is functionally compatible with the Tube-launched, Optically-tracked, Wire-guided (TOW) Missile Night Sight (AN/TAS-4) optics so

that standard IR performance measures can be applied to the binary optics telescope. The tunable electron-grating laser design is continuing with emphasis on resonant cavity design.

In the Millimeter Wave Autonomous Sensor program, an extensive research program is continuing to develop and optimize battlefield target detection/classification algorithms. Fabrication of an airborne radar testbed will continue and preparations for collection of a comprehensive high resolution target/background signature database will be initiated. This test bed will measure the full polarization matrix return from targets. This will provide quality target and clutter signatures for algorithm development.

In the Small Unit Technology program, development of the Swimmer Delivery Vehicle part-task trainer prototype is continuing with enhancements directed at Naval Special Warfare special missions, development of a concept demonstrator version of a small unit simulator is continuing, and a small/special weapons and close quarters combat trainer concept demonstrator is being constructed. First flight of the Advanced Technology Tactical Transport proof of concept demonstrator will occur. An acoustic detection system project is being initiated, as are projects on unattended ground sensors and unique power sources and special communications techniques for small units.

The Tactical Expert Mission Planner (TEMPLAR)/Air Land Battlefield Management (ALBM) interface design and prototype will be completed. Prototype demonstrations of Air Tasking Order (ATO) generation have been accomplished.

c. FY 1988 Planned Program and Basis for FY 1988 Request: European theater demonstration of the area search reduction and indications and warning components of the Tactical Use of National Technical Means program will be conducted. Development and test of target detection and classification algorithms will continue. Development of target identification algorthms will begin. The tracking methodology will be evaluated.

Transfer of the Remotely Piloted Vehicle (RPV) Surveillance Radar program to the Army will be completed. Plans to incorporate new modes, including medium-resolution radar imaging and the incorporation of target classification algorithms developed under the Millimeter Wave (MMW) Autonomous Sensor program, are on hold due to funding shortfalls.

In the Autonomous Infrared (IR) Sensor program, an image collection program will be executed in conjunction with the Millimeter Wave (MMW) Autonomous Sensor program. This imagery will constitute the first high quality multi-sensor signature database for use in developing advanced target detection and classification algorithms/software. The data will be provided to the Smart Weapons prime contractors under the Strategic Computing program, and other algorithm developers. Development of image metrics and algorithm performance evaluation techniques will continue.

In the Uncooled Sensor arrays program, the High Density Arrays Development will continue with intermediate experiments on scaleable sensor technology and small array imaging demonstrations. Development of the Anti-Ship Seeker will continue with

integration of arrays into captive flight testbed weapons package. The seekers will be readied for a comparative flight test program.

In the Infrared Binary Optics program, MIT/Lincoln Laboratory (LL) will continue experiments on addition of short wavelength lasers (e.g. ultraviolet) and to refine theory/implementation concepts for the continuously unable detection-grating laser. Under subcontract(s) to industry, work will proceed toward demonstration of an advanced application of binary optics either as a low-cost passive Infrared (IR) telescope or as the enabling technology for modular laser radars. Also at MIT/LL, experiments will be conducted to evaluate further applications, especially large, lightweight low-cost optics, e.g. one meter diameter apertures for high performance tactical and strategic system.

In the Millimeter Wave (MMW) Autonomous Sensor program, checkout of the MMW target/clutter signature collection testbed will be completed and an extensive database will be established of the radar signature data gathered. Contractors and laboratories who have heretofore been using interim data will begin working more intensively with the new data. Concepts and designs for a new generation of MMW smart seekers, surveillance and target acquisition radars will be developed.

The Small Unit Technology program: The Swimmer Delivery Vehicle will be evaluated and transitioned to the Navy. The small unit simulator will be evaluated in a stand-alone mode for direct action and strategic reconnaissance missions. The first phase special weapons and close quarters combat trainer will be evaluated. The Advanced Technology Tactical Transport concept demonstrator will be flight tested and the acoustic detection system laboratory development will continue. Based on the results of the unattended ground sensors and special communications survey, technology development will be initiated.

The Tactical Expert Mission Planner (TEMPLAR)/Air Land Battlefield Management (ALBM) have been linked and demonstrated. Air Tasking Order (ATO) portions relating to close air support and defensive counter-air will be associated with ALBM in a cooperating expert system mode.

In the Smart Weapons Program a single contract will be competitively awarded for the development of an intelligent munitions demonstration testbed. The Intelligent Munitions (IM) will be capable of the following high level autonomous functions: limited area search, target recognition, countermeasure rejection, target selection, arm point selection and terminal guidance. This program will be closely coordinated with advanced computing hardware and software developments in Strategic Computing (ST-10).

d. FY 1989 Planned Program and Basis for FY 1989 Request: In the Tactical Use of National Technical Means program, algorithms and techniques will be installed on Strategic Computing initiative machines which will serve as a testbed for the integrated system. Algorithms for target identification and detection will be evaluated as will techniques for prediction of local weather in denied areas as they impact on tactical ballistic missile mobility.

Project: TT-05
Program Element: #62702E
USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

In the Autonomous Infrared Sensor Technology program, the signature collection program will be completed. All data will be made available to industry/government for future exploitation. The results of the image metric and algorithm evaluation experiments will be fully documented in a series of reports. The program activities will be transitioned to the Services and the Automatic Target Recognizer Working Group (ATRWG) for sensor data, image metrics and evaluation of algorithm performance.

In the Uncooled Sensor Arrays program, the High Density Array Development will conclude with image demonstration of full pixel arrays and sensitivity. The program will transition to the Army for exploitation in several applications such as a low cost thermal driving aid for combat vehicles and a compact weapons sight for land combat. The uncooled Anti-Ship Seeker will undergo a flight evaluation experiment to demonstrate lock-on-after-launch of ship targets. The program will transition to the Navy.

In the Infrared (IR) Binary Optics program, the subcontractor will complete development of either a low cost telescope or modular fire control system. The delivered item will be evaluated and results will be reported to the IR community for transition to the military. Optimization of the tunable electron-activated laser will continue leading to demonstration in application oriented experiments. Large area optics (one meter diameter) will be fabricated and evaluated.

Development of target detection/classification techniques by the Millimeter Wave (MMW) Autonomous Sensor program will be completed in FY 1989. Concept designs for new seekers and fire control radars will be evaluated and development initiated in FY 1989. Results for this task will be continuously transferred to the Services via a tri-Service technical liaison activity.

The fabrication of the Smart Weapons Intelligent Munitions will continue. Subsystems will be delivered and tested. Software will be validated prior to installation in flyable computer hardware.

e. Program to Completion:

The Millimeter Wave (MMW) Sensor program will transition to the Services in FY 1990. The sensor will be transitioned to the Air Force for seeker development and bistatic radar experiments.

The integrated Tactical Use of National Technical Means (TACNAT) testbed will be a resource for new sensor algorithm development and for test and evaluation of techniques contributing to holding relocatable targets at risk. Components of the programs will be transitioned to a variety of operational users.

The Small Unit Technology program will focus on transition of projects to the Services upon completion of their exploratory research components during late FY 1989. For example, the Advanced Technology Tactical Transport flight tests will have been completed as part of the transfer requirements in late FY 1987. The Swimmer Delivery Vehicle trainer and mission rehearsal aid will be transitioned as will the Small and Special Weapons Trainer. Testing of the linkage of the Joint Special Operations Simulation with the USAEUR Warrior Preparation Center conventional theatre models will be conducted. The acoustic detection system will be transitioned and development will continue on special communications.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: TT-05
Program Element: #62702E
USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

Under the Infrared (IR) Binary Optics program, the Long Wave Infrared wideband telescope will be installed on a tactical thermal Tube-launched, Optically-tracked, Wire-guided (TOW) Missile Night Sight; its performance will be compared with conventional germanium optics. A compact laser radar will be demonstrated using all binary optics; the system will be flown as part of a tactical weapons delivery program.

The Smart Weapons Intelligent Munitions demonstration testbed will be completed and delivered to the test site in FY 1991 where it will undergo flight tests. Complete design information will be disseminated to industry and the Services for transition in FY 1992.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestones
Tactical Use of National Technical Means Program		
--	Mid FY 1988	Demonstration of program components in European theatre.
--	Mid FY 1989	Evaluation of tracking methodology. Evaluation of identification and algorithm evaluation.
--	Late FY 1989	Integrated system testbed.
Surveillance Radar Program:		
Early FY 1987	Late FY 1987	Captive flight test, Remotely Piloted Vehicle (RPV) radar.
Early FY 1988	Early FY 1988	Free flight test, Remotely Piloted Vehicle (RPV) radar. (Pending funding)
Autonomous Infrared Sensor Program:		
--	Late FY 1987	Signatures collected on surface-to-surface missiles.
--	Late FY 1988	Image metrics and algorithm evaluation techniques fully established.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: TT-05
Program Element: #62702E
USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestones
Uncooled Infrared Sensor Arrays Program:		
--	Late FY 1989	Signature collection completed. Transition metrics and evaluation technology to Services.
Mid FY 1987	Mid FY 1987	Image partial arrays, high sensitivity; design of the anti-ship seekers.
Late FY 1988	Late FY 1988	Demonstrate high density imaging, anti-ship seeker. Program transition to Service development program.
Millimeter Wave Autonomous Sensor Program:		
Early FY 198-	Early FY 1988	Airborne Millimeter Wave (MMW) testbed radar developed and data collection begun.
Late FY 1988	Late FY 1989	Data collection and algorithm research to be completed.
Late FY 1988	Late FY 1989	Seeker designs will be delivered.
Early FY 1989	Early FY 1990	Seeker designs evaluated and transitioned to the Services.
Small Unit Technology Program:		
Mid FY 1987	Mid FY 1987	Transfer of Swimmer Delivery Vehicle Part Task Trainer to the Navy.
Late FY 1987	Late FY 1987	Advanced Technology Tactical Transport (AT^3) flight tests.
Late FY 1988	Late FY 1988	Transfer of Small Unit Planning Aid to Special Operations Forces and AT^3 to the Services.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: TT-05
Program Element: #62702E
USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestones
Tactical Expert Mission Planner/Air Land Battlefield Management		
--	Late FY 1987	Initiate Tactical Expert Mission Planner (TEMPLAR)/Air Land Battlefield Management (ALBM interface design and construction.
--	Late FY 1988	Demonstrate TEMPLAR/ALBM interface in the Continental United States (CONUS).
--	Late FY 1989	Demonstrate interface in the European Command (EUCOM).
Infrared Binary Optics Program:		
Early FY 1986	Mid FY 1987	Award contract for applications demonstration of low-cost infrared (IR) telescope or laser radar.
Mid FY 1987	Late FY 1987	Demonstrate lab version of low-cost Tube-launched Optically-tracked Wire-guided (TOW) telescope.
Late FY 1987	Late FY 1988	Demonstrate tunable laser.
	FY 1989	Deliver low-cost telescope or modular laser radar.
Late FY 1987	Late FY 1987	Demonstrate laboratory laser radar.
Smart Weapons		
	FY 1988	Award contract for Intelligent Munitions demonstration testbed.
	FY 1989	Software and subsystem qualification.
	FY 1990	Integration of subsystems into testbed. Preflight checks.
	FY 1991	Flight program.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: TT-05
Program Element: #62702E
USDR&E Mission Area: 530

Title: Target Acquisition and Weapons Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestones
	FY 1992	Report and transition to Services.

g. Explanation of Milestone Changes:

The changes indicated in the Millimeter Wave (MMW) Autonomous Sensor program reflect an eight month delay in contract award for algorithm development contracts and a program slip in the radar development due to funding cuts. The small change in Uncooled Infrared Sensor Army program represents more realistic assessment of when anti-ship seeker will be demonstrated. Changes in Infrared Binary Optics program are a result of the Gramm-Rudman budget cuts.

In FY 1986 the Tactical Use of National Technical Means program was initiated with a small amount of funds after submission of the FY 1987 Descriptive Summary.

Development and fabrication of the Advanced Technology Tactical Transport has proceeded more rapidly than anticipated.

Acoustic Charge Transport Program was transferred to PE 61101E due to applied research nature of the programs.

The Hemispherical Resonator Gyroscope Program was terminated in Mid FY 1986 due to Gramm-Rudman-Hollings cuts.

Advanced Ramjet Munitions was transferred to TT-04 where it is now part of the Armor/Anti-Armor program and milestones are reported in that project.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #TT-06
Program Element: #62702E
USDR&E Mission Area: 530

Title: Tactical Directed Energy Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The objective of the Tactical Directed Energy Technology Project is to develop moderate-power efficient high-brightness lasers and high-power microwave source and antenna technology for a broad spectrum of tactical, military applications. This project includes efforts focused on the development of (1) new compact, efficient, frequency-agile solid state lasers and (2) tunable high-power microwave source/antenna development. Some efforts of the Strategic Defense Initiative Organization (SDIO) are complementary, however much of their work is not appropriate to tactical applications since (1) the laser brightness required for tactical applications is about six to eight orders of magnitude less than that required for ballistic missile defense applications and (2) scaling down the SDIO laser technology is an inappropriate and expensive alternative to the approaches described herein to achieve the compactness and frequency agility required for conventional tactical applications.

The 1985 Defense Science Board Summer Study on Tactical Directed Energy Weapons (DEW), affirmed the importance of the Tactical Directed Energy project started by DARPA in FY 1985. The DARPA project focuses on the conventional needs of the tactical battlefield. The technologies being developed will enable the Services to develop tactical directed energy weapon systems (TDEWS) that are effective in the countermeasured battlefield environment. These systems will be compatible with friendly forces (no fratricide) and are low cost so that many TDEWS could be procured. The DARPA investment in TDEW technology is a springboard for potential joint DARPA/Service TDEWS prototype development.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: Considerable progress was made by a government/industrial team led by Lawrence Livermore National Laboratory (LLNL) in developing the materials science base and in developing the design tools for understanding and breaking through the historical barriers to high efficiency, good beam quality and wavelength agility in medium power solid state lasers. Testbeds were built which verified predictions of design codes. Surface treatment and coating processes were developed to increase the average power capability of solid state lasers. Seven centimeter diameter size boules of

Project: #TT-06
Program Element: #62702E
USDR&E Mission Area: 530

Title: Tactical Directed Energy Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

chromium and neodymium co-doped gadolinium scandium gallium garnet (Nd:Cr:GSGG) have been grown. When further developed in larger boules and to have low optical losses, Nd:Cr:GSGG provides higher average power capability at greater efficiency than neodymium doped Yittrium Aluminum Garnet (Nd:YAG). The cavity resonator components for a 70 cm Zig-Zag neodymium doped glass slab laser were designed, constructed and assembled. This laser is being used as a versatile testbed in FY 1987 experiments.

Approaches to developing low cost, frequency-agile, compact lasers were evaluated. The investigation of combustible gas implosions as an optical pump source was discontinued because of low output efficiencies. This investigation continues in laboratory experiments and computer simulations to improve the efficiency by a factor of 20. The progress made in improving the output power and efficiency of the semiconductor laser diode array in project ST-09 and in industry's Internal Research and Development programs suggested that they are the ideal pump sources for compact lasers provided the cost of the laser diode array could be reduced by a factor of 100 or more. Good progress was made in developing nonlinear optical materials such as Potassium Titanium Phosphate for the efficient harmonic conversion of Neodymium 1.06 um laser.

To avoid possible duplication of effort, DARPA postponed work related to free electron microwave (FEM) devices. Both the FEM technology for generating high power microwaves and the phenomenology of susceptibility of electronics to high power microwaves appear to be adequately covered by Strategic Defense Initiative Organization (SDIO) and Service sponsored programs.

b. FY 1987 Program: In FY 1987, DARPA continues to develop the technology base for the Tactical Directed Energy project.

One major objective is to develop the technology and materials science base for a medium-power solid state laser system. The current phase is a four year, $30M total, research and exploratory development phase. This phase is jointly funded with ST-09, which provides about one third of the funding. FY 1987 marks the mid point of this effort. In FY 1987, the 70 cm Zig-Zag slab laser is used as a testbed to demonstrate the operation of a series of different laser slab thickness to confirm predictions of output energy, efficiency and pulse repetition rate.

Project: ITT-06
Program Element: #62702E
USDR&E Mission Area: 530

Title: Tactical Directed Energy Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

A number of firsts in free world accomplishments in solid state laser technology is the anticipated development and use of low optical loss glass slabs to improve output efficiency; and, the anticipated development and growth of 13 cm diameter boules of co-doped Nd:Cr:GSGG for use in slab lasers.

c. FY 1988 Planned Program and Basis for FY 1988 Request: In FY 1988, the medium power solid state laser technology base program will be completed. The program will demonstrate high efficiency, high pulse repetition rate laser operation using both Nd:Glass and crystalline laser media as well as wavelength conversion and good beam quality.

Depending on the progress made in the research on high explosive driven optical sources, a number of brassboards will be produced to enable the Services to explore the operational utility of these devices.

The man-portable brassboard will be completed. Competitive designs of advanced engineering models incorporating advances in laser materials, non-linear materials and techniques, pulse forming network and batteries will be started. A number of these "prototype" models will be developed to meet both performance and cost goals.

d. FY 1989 Planned Program and Basis for FY 1989 Request: The development of advanced engineering models of lasers will continue. These units will be completed in FY 1990 and be tested in the field by the Services. The "prototype" models and their field evaluation will enable the Services to proceed to full-scale engineering development, if needed.

The design of a transportable high power microwave source and antenna brassboard for advanced surveillance and/or anti-smart weapon (e.g., terminally guided submunition) applications will be started.

Competitive designs of advanced engineering model incorporating better system concept ideas, breakthroughs in solid state laser technology and advances in phase conjugation technology, all packaged to fit a high value weapon platform, to enhance the platform's fire power will be started. One or more of these "prototype" models will be developed to meet both performance and cost goals. Depending on the platform chosen, this project will be a $50 to 100 million investment over four years.

Project: #TT-06
Program Element: #62702E
USDR&E Mission Area: 530

Title: Tactical Directed Energy Technology
Title: Tactical Technology
Budget Activity: 1. Technology Base

e. Program to Completion: This is a continuing effort. The advanced engineering models will be completed and evaluated, and decisions made for future demonstration and prototype efforts as well as for engineering development by the Services.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestone
--	Late FY 1990	Development of advanced engineering models of lasers.

g. Explanation of Milestone Changes: No significant changes.

I. TEST AND EVALUATION DATA: Not Applicable.

J. COOPERATIVE AGREEMENTS: Not Applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62707E
USDR&E Mission Area: 530

Title: Particle Beam Technology
Budget Activity: 1. Technology Base

A. RESOURCES: ($ in thousands)

Project Number	Title	FY 1986 Actual	FY 1987 Estimate	FY 1988 Estimate	FY 1989 Estimate	Additional to Completion	Total Estimated Costs
	TOTAL FOR PROGRAM ELEMENT	$17,500	$14,500	$14,000	$14,000	Continuing	

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This program supports basic research and technology development to determine the scientific feasibility of particle beam weapon concepts which have the advantages of near speed-of-light delivery, rapid retargeting, and deep target penetration with a variety of kill mechanisms. The major objective of this effort is to demonstrate stable, predictable propagation of a relativistic electron beam within the atmosphere for potential point defense applications. To this end, DARPA developed and constructed the Advanced Test Accelerator (ATA) at the Lawrence Livermore National Laboratory as the program's major experimental installation. Through FY 1984, this program also supported research on the production of high-brightness neutral particle beams for potential space applications including satellite and ballistic missile defense. In FY 1985, the neutral particle beam program and certain elements of the charged particle beam program directed toward research of space-based electron beam weapon concepts were transferred to the new Strategic Defense Initiative Organization.

C. COMPARISON WITH FY 1987 DESCRIPTIVE SUMMARY: Gramm-Rudman-Hollings and other undistributed budget reductions reduced the funds programmed for this element by $2.5 million (from $20 million). This reduction together with additional delays associated with the Strategic Defense Initiative Organization (SDIO) Paladin (Free Electron Laser) Experiment significantly slowed performance on key program milestones.

Lead pulse experiments were performed during FY 1986 with very favorable results. Further data analysis will continue, but it is believed that these experiments substantially satisfy the major milestone for lead pulse stability. The second major milestone, demonstration of pulse-to-pulse tracking, will be addressed next. To exploit this significant progress, DARPA is now planning to continue the Particle Beam Technology program past FY 1987 with the objective of demonstrating all of the crucial physics of endoatmospheric propagation.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62707E
USDR&E Mission Area: 530

Title: Particle Beam Technology
Budget Activity: 1. Technology Base

D. OTHER APPROPRIATION FUNDS: None.

E. RELATED ACTIVITIES: In FY 1980 the Under Secretary of Defense for Research and Engineering approved the Particle Beam Technology Program which, beginning in FY 1981, consolidated the DoD particle beam efforts under the overall technical direction of DARPA. Under this plan, DARPA assumed responsibility for both charged and neutral particle beam feasibility experiments. The Military Departments were responsible for advancing those technologies, which are essential in order to rapidly develop particle beam weapons once they are proven feasible. In FY 1983, the transition to Army support began for the neutral particle beam program. This work is presently being continued under the sponsorship of the Strategic Defense Initiative Organization (SDIO).

F. WORK PERFORMED BY: This effort is performed by in-house activities (5%), by federally funded research facilities (85%) and by industrial contractors (10%). In-house participants include: the Naval Surface Weapons Center, Silver Spring, Maryland; and the Naval Research Laboratory, Washington, D.C. Federally funded research facilities include the Lawrence Livermore National Laboratory, Livermore, California; and Sandia National Laboratories, Albuquerque, New Mexico. Industrial contractors include Science Applications International Corporation, Palo Alto, California; SRI International, Menlo Park, California; AVCO Everett Research Laboratory, Everett, Massachusetts; Mission Research Corporation, Santa Barbara, California; C.S. Draper Laboratories, Cambridge, Massachusetts; McDonnell Douglas Research Labs, St. Louis, Missouri; and Pulse Sciences, Inc., Oakland, California.

G. PROJECTS LESS THAN $7 MILLION IN FY 1988-1989: Not Applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62707E
USDR&E Mission Area: 530

Title: Particle Beam Technology
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: Charged particle beam concepts are being considered for applications in a variety of advanced weapon systems. The reason for interest in these concepts is the expectation that particle beams can deposit large amounts of energy (megajoules) deep within a target to deliver near instantaneous, diagnosable, hard kill at close to the speed of light.

The key issue for development of charged particle beam concepts is the capability to propagate electron beams in the atmosphere. Theoretical models for electron beam propagation have been developed and have been verified by low-energy experiments at sub-atmospheric densities. However, until now, no electron accelerators of sufficient energy and current has existed in the free world which would permit critical propagation experiments to be performed at full atmospheric densities. Such experiments are essential. These experiments are being conducted by DARPA on the Advanced Test Accelerator (ATA), and on Radial Line Accelerator (RADLAC-II), an accelerator developed jointly by Sandia National Laboratory and the Air Force Weapons Laboratory. RADLAC-II is capable of less energy but greater current, which greatly extends the parametric limits of beam propagation that can be explored.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: During FY 1986, propagation experiments were conducted which demonstrated and verified predictions of lead pulse stability at the Advanced Test Accelerator at the Lawrence Livermore National Laboratory. These results go beyond a similar stable lead pulse propagation experiment in full density air at the Sandia National Laboratory during FY 1985.

Theoretical efforts during FY 1986 were turned towards the second major milestone of the Charged Particle Beam (CPB) propagation program, successful pulse/channel tracking. This phenomenon must be understood and controlled to achieve propagation to long distance. Two theoretical teams have completed computer calculations which predict the conditions for tracking. Designs and preparations for pulse/channel tracking physics experiments were started.

Program Element: #62707E
USDR&E Mission Area: 530

Title: Particle Beam Technology
Budget Activity: 1. Technology Base

b. FY 1987 Program: In FY 1987, experiments are planned to propagate the ATA beam. This experiment is expected to yield important lethality data including the lethality of high current electron beams against conventional high explosive warheads. Other important information to be collected include secondary kill mechanisms as well as mapping of the beam's radiation and electromagnetic fields.

In addition to these experiments, preparations are also being made for experiments to measure ability of a subsequent beam pulse to sense and follow the path of a preceding pulse. This is a complicated problem involving time dependent, nonlinear beam air chemistry, kinetics, electrodynamics, and hydrodynamics. The size, conductivity, and orientation of the channel can be varied to determine configurations which yield maximum positive tracking force.

c. FY 1988 Planned Program and Basis for FY 1988 Request: In anticipation of positive results in the FY 1987 experimental program a second set of experiments is planned.

Aside from the propagation issue, production of accelerators small enough and light enough to be useable in the battlefield is the most difficult problem for future weaponization. To support the propagation program in both FY 1988 and FY 1989, DARPA will pursue a modest program in the development of compact accelerator technology.

d. FY 1989 Planned Program and Basis for FY 1989 Request: Success in the FY 1987 and FY 1988 experiments will provide the impetus to modify either RADLAC (SNL) or Advanced Test Accelerator (LLNL) to perform an actual two-pulse pulse tracking experiment. A decision to proceed will initiate in FY 1990 a more complete demonstrations of propagation as well as increased efforts by the Services to develop light, compact accelerator technologies appropriate to each Service mission.

e. Program to Completion: The plan for the Charged Particle Beam Technology Program for FY 1987-1989 is built around the accomplishment of three essential experiments.

Program Element: #62707E
USDR&E Mission Area: 530

Title: Particle Beam Technology
Budget Activity: 1. Technology Base

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestone

g. Explanation of Milestone Changes: Funding reductions and reduced availability of Advanced Test Accelerator to favor increased support of the programs of the Strategic Defense Initiative Organization have resulted in delays.

I. TEST AND EVALUATION DATA: Not Applicable.

J. COOPERATIVE AGREEMENTS: Not Applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62708E
USDR&E Mission Area: 530

Title: Integrated Command and Control Technology
Budget Activity: 1. Technology Base

A. RESOURCES: ($ in thousands)

Project Number	Title	FY 1986 Actual	FY 1987 Estimate	FY 1988 Estimate	FY 1989 Estimate	Additional to Completion	Total Estimated Costs
TOTAL FOR PROGRAM ELEMENT		41,793	43,450	36,435	38,400	Continuing	N/A
IC-01	Distributed Information Systems	20,440	21,984	16,885	17,580	Continuing	N/A
IC-02	Advanced Command, Control and Communications Technology	21,353	21,466	19,550	20,820	Continuing	N/A

B BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: The objective of DARPA's research in Integrated Command and Control technology is to develop advanced information processing and computer-communications technology which provides a base for future command and control systems, and to demonstrate and evaluate them with the Services and our Allies in selected operational environments. A heavy emphasis is placed on the development of distributed communications and processing technologies to enhance survivability.

C. COMPARISON WITH FY 1987 DESCRIPTIVE SUMMARY: Decreases in FY 1986-1987 are due to undistributed Congressional reductions and Gramm, Rudman and Hollings cuts.

D. OTHER APPROPRIATION FUNDS: None.

FY 1988-1989 RDT&T DESCRIPTIVE SUMMARY

Program Element: #62708E
USDR&E Misslon Area: 530

Title: Integrated Command and Control Technology
Budget Activity: 1. Technology Base

E. RELATED ACTIVITIES: The Internet effort ls coordinated with the Defense Communlcatlons Agency (DCA) and the Services. The Defense Data Network ls utlilzing the DARPA-developed Internet protocols. Efforts to achieve interoperabiiity of command and controi are belng coordinated with the U.S. Army Communications-Electronics Command (CECOM), the USAF Eiectronic Systems Command, and the USAF Rome Alr Development Center (RADC). Aii conduct research in packet-switching based on the DARPA research results. RADC ls also fundlng and coordinatlng efforts in distributed processing technology. A joint effort is being conducted with the Nationai Science Foundatlon (NSF) to support a key initiatlve for access to supercomputer resources. The Strategic Command, Controi, and Communications Experiment ls a joint effort with the Strategic Air Command (SAC), RADC and DCA. A Survivable Adaptive Pianning Experiment (SAPE) ls being initiated as a joint DARPA, SAC, RADC, and Joint Strategic Target Pianning Staff (JSTPS) program to deveiop survivabie adaptive network technoiogy with strategic mission plannlng capabiiities. The Ft. Bragg testbed is a joint effort with the Army, with CECOM playing the lead roie with the Experimentai Integrated Switched Network effort of DCA and the Services. Development of security devices for the tacticai environment is being carried out jointly with the National Security Agency and CECOM. Design tools are being developed by the Ada Joint Program Office and the Software Technoiogy for Adaptabie and Reliable Systems activity.

F. WORK PERFORMED BY: Universities 55%, Industry 40%, In-house 5%. The major performers are University of Southern California/Information Sciences Institute, Marina dei Rey, California; Bolt, Beranek and Newman, Cambridge, Massachusetts; SRI Internationai, Menio Park, California; Stanford Universlty, Stanford, California; Carnegie-Meiion Unlversity, Pittsburgh, Pennsylvania; Massachusetts Institute of Technology, Cambridge, Massachusetts: MIT Lincoln Laboratory, Lexington, Massachusetts; Hazeltine Corporation, Greenlawn, New York; University of California at Berkeley, Berkeley, California; Rockwell Internationai, Richardson, Texas; Perceptronics, Woodland Hills, California.

G. PROJECTS LESS THAN $7 MILLION IN FY 1988-1989: Not Applicabie.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #_IC-1
Program Element: #62708E
USDR&E Mission Area: 530

Title: Distributed Information Systems
Title: Integrated Command and Control Technology
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN 1988-1989:

1. Project Description: The objectives of this project are to develop and demonstrate technology for building geographically distributed information systems which can handle classified data, meet specific real-world time constraints, and be easily expanded to meet the increasing demand for information processing in DoD command control and communications applications. Techniques are being developed to support secure distributed processing among computers on different packet networks. Mechanisms to control and regulate the performance of the Internet environment are being developed. Distributed operating systems, message systems, data bases and programming environments are being developed, along with several applications which run in a distributed environment of personal workstations. Local and long-haul methodologies are being developed for real time, large scale networks of interactive simulators which permit combat teams to practice critical unit skills at a fraction of the cost of today's infrequent field exercises. Advanced prototype software development and design environments suitable for Ada are being developed for use in a local network of advanced workstations using distributed systems technologies. Advanced distributed systems architectures are being explored and prototypes developed to enable the effective operation of a large-scale, heterogeneous, open system that will work with Strategic Computing architectures. This will provide the kind of resource sharing and interoperability required to support the insertion of Strategic Computing technologies (PE 62301E, Project ST-10) into the distributed systems technology base.

2. Program Accomplishments and Future Programs:

a. FY 1988 Accomplishments: Techniques were demonstrated for distributed real-time applications operating on the Internet system to support multi-media conferencing. New end-to-end communication services were developed and demonstrated to support such applications. Interoperability of the Internet system with commercial systems was demonstrated, including electronic mail and appropriate charging mechanisms. Experimentation, evaluation and demonstration advanced algorithms for tracking of multiple targets, information fusion of multiple views and

Project: # IC-1
Program Element: #62708E
USDR&E Mission Area: 530

Title: Distributed Information Systems
Title: Integrated Command and Control Technology
Budget Activity: 1. Technology Base

multiple media, and position self-location were performed. The experimental portion of the distributed sensor network program was completed. The Internet Private Line Interface (IPLI) was completed and passed TEMPEST testing. The planning was completed to provide compartmentation of a secure local network in a demonstration system based on a previously developed DES encryption device. The Diamond multimedia message system running on advanced scientific workstations was tested by military users in the Ft. Bragg testbed (Project IC-2). New network partition-recovery mechanisms developed to support the Strategic Air Command (SAC) testbed (Project IC-2) were thoroughly tested and enhanced. The SIMNET (Simulator Networking) network of training simulators was expanded to six full crew M1 battle tank simulators and is supporting tactical operations center and command and control nodes on a local area network at Ft. Knox, Kentucky. Training evaluations demonstrated the potential of this technology for developing critical, high cost war fighting skills.

b. FY 1987 Program: Techniques are being developed to support a very large number of nodes on the Internet as well as to move large amounts of priority ordered data. Interoperability of the Internet with commercial systems is being explored and demonstrated. Development of interoperability techniques with OSI standards and NATO C3 systems are being explored. Applications of very high speed networking is being explored along with the protocols and techniques needed to support such applications. Design, integration, and implementation is beginning on a new distributed operating system nucleus based on advanced object-oriented design techniques (MACH), which will provide distributed system support for other software systems such as the UNIX operating system and an Ada programming environment running as server processes. The distributed sensor network program will be completed with publication of a book describing the theoretical foundations, algorithms, and techniques developed and validated. Interim and final certifications of the Internet Private Line Interface (IPLI) are being obtained to permit its use as an end-to-end encryption device for sending classified data through a tactical packet-switched internet. Design engineering is being accomplished for a high speed encryption device which will provide security for data transmitted between ARPANET sites. The Ft. Knox SIMNET (Simulator Networking) test site will be expanded to test a full battalion of combat simulators (82) interacting in real time on a local area network. A

Project: # IC-1
Program Element: #62708E
USDR&E Mission Area: 530

Title: Distributed Information Systems
Title: Integrated Command and Control Technology
Budget Activity: 1. Technology Base

second site at Ft. Benning will be started and the development of long haul networking between the two sites will begin. Prototype development of an advanced prototype software development and design that can support Ada environment using distributed system technology is starting. Advanced software engineering laboratories are being established to support software development and design environment research and technology transition.

c. FY 1988 Planned Program and Basis for FY 1988 Request: Techniques will continue to be developed to support a very large number of nodes on the Internet as well as to move large amounts of priority ordered data. Interoperability among C3 systems will continue to be explored. Continued interoperability with OSI standards will be developed. Very high speed networking will continue to be explored along with the protocols and techniques needed to support applications on such networks. Ada and MACH will be used to explore new methodologies for developing C3 systems. Object based image communication techniques will be explored in a multi-media environment. Techniques for managing complex, multimedia networks and integrated networks will be explored. Security requirements and architectures will be explored for Internet technology and experimental networks. Distributed systems technology will be explored for use in distributed C3 cystems. Design and implementation will begin of a new distributed operating system nucleus based on advanced object-oriented design techniques; this nucleus will provide distributed system support for other software systems such as the UNIX operating system and an Ada programming environment. Two SIMNET sites will be activated and long-haul networking will be tested. SIMNET testing between three sites in the U.S. will commence attempting to allow three battalions of combat vehicle simulators (240) to interact in large force-on-force exercises. A fourth site in Europe is being initiated. Design of the advanced prototype Ada environment will be completed and prototype development started. Advanced distributed systems architectures will be prototyped and evaluated as a new foundation for the insertion of Strategic Computing technologies.

d. FY 1989 Planned Program and Basis for FY 1989 Request: End-to-end encryption devices will be installed to provide privacy for ARPANET data traffic. Techniques will continue to be developed to support a very large number of nodes on the Internet as well as to move large amounts of

Project: # IC-1
Program Element: #62708E
USDR&E Mission Area: 530

Title: Distributed Information Systems
Title: Integrated Command and Control Technology
Budget Activity: 1. Technology Base

priority ordered data. Interoperability among C3 systems will be explored. Continued interoperability with OSI standards will be developed. Very high speed networking will continue to be explored along with the protocols and techniques needed to support applications on such networks. Ada and MACH will be used to explore new methodologies for developing C3 systems. Object-based image communication techniques will be explored in a multi-media environment. Techniques for managing complex, multimedia/conferencing networks and integrated networks will be explored. Security requirements and architectures will be explored for Internet technology and experimental networks. Distributed systems technology will be explored for use in distributed C3 systems.

e. Program to Completion: The Internet environment will become a tightly integrated network of networks. Interoperability with other protocol systems will be explored. Techniques will be developed and demonstrated for providing the required real-time data communication to support distributed command and control applications in an Internet environment. Techniques will be developed and demonstrated to permit a locally specified tradeoff between transparency and autonomy in a distributed operating system. Mechanisms will be developed which permit integrated operation of very large distributed systems with thousands of nodes. A distributed operating system will be developed and demonstrated in which support of nodes spread across an integrated network is included in the fundamental design of the system. A distributed system design approach will be developed in which the distributed and fault-tolerant nature of replicated objects is a basic property of the objects themselves, allowing the designer of a distributed application to proceed as if he were creating a simpler non-distributed design. Four SIMNET test sites will be populated with battalion sized task forces of combat simulators (tanks, armored personnel carriers, helicopters, and fighter aircraft) to evaluate the SIMNET concept and establish the DoD standards for large scale interactive simulator networks. A prototype advanced Ada environment will be developed suitable for use with a new generation of AI-based software and system tools. The new distributed operating system nucleus will be implemented in Ada using advanced software engineering and formal specification techniques. The computing environments of major research centers will transition to the new foundation of

Project: # IC-1
Program Element: #62708E
USDR&E Mission Area: 530

Title: Distributed Information Systems
Title: Integrated Command and Control Technology
Budget Activity: 1. Technology Base

advanced distributed systems to enable the exploitation of a new machine intelligence base developed by the Strategic Computing program.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestone
Early FY 1986	Mid FY 1987	Certify manually rekeyed end-to-end encryption system for use at Fort Bragg and SAC testbeds.
- -	Mid FY 1987	Install eight M2 simulators (two platoons) at Ft. Benning.
- -	Mid FY 1987	Complete design of advanced prototype Ada programming environment.
Mid FY 1987	Mid FY 1987	Complete initial design of object-based distributed operating system nucleus.
- -	Mid FY 1988	Demonstrate IP level interoperability between DoD and OSI standard protocols
Late FY 1988	Late FY 1988	Complete initial prototype of new distributed systems foundation.
- -	Mid FY 1989	Demonstrate distributed, large scale C3 system across the Internet.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #_IC-1
Program Element: #62708E
USDR&E Mission Area: 530

Title: Distributed Information Systems
Title: Integrated Command and Control Technology
Budget Activity. 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestone
Mid FY 1986	Late FY 1989	Initiate installation of privacy devices on ARPANET.

g. Explanation of Milestone Changes: Certification of end-to-end security device (the IPLI) for the Ft. Bragg and Strategic Air Command (SAC) testbeds is delayed due to technical problems with the hardware. Milestone date for initiation of ARPANET privacy effort is relying upon commercial development of appropriate devices.

I. TEST AND EVALUATION: Not applicable.

J. COOPERATIVE AGREEMENT: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: # IC-2
Program Element: #62708E
USDR&E Mission Area: 530

Title: Advanced Command Control Communications Technology
Title: Integrated Command and Control Technology
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The objectives of this project are to develop and demonstrate advanced command and control technology and transfer it to the Services and Agencies. Survivable, intelligent networks are being explored which can function in the presence of jamming, spoofing and the loss of communication resources; and techniques are being developed for utilizing and controlling large-scale communication networks consisting of hundreds of nodes. A testbed is being developed to support experimentation with large-scale networks. A survivable communications network architecture consisting of multiple, low-orbiting, low-cost satellites is being investigated. A methodology is being developed for rapid implementation of prototype systems which uses computing technology and communication networks to permit the separation of the design and fabrication processes with the goal of reducing the development time for critical Defense components from completed design to finished project to a few weeks. The Army/DARPA Distributed Communication and Processing Experiment (ADDCOMPE), a joint testbed program, is being carried out with the Army at Fort Bragg NC and other key locations to develop distributed ADP applications for evaluation in a tactical operational environment. From this effort there will evolve innovative system concepts for the use of computers in support of future Army requirements. In addition, doctrine will be developed for distributed processing in the Army for the 21st century. Secure multimedia conferencing architectures, protocols and devices will be developed and validated in the Internet system. Architectures, techniques and tools for constructing very large evolutionary command and control systems will be developed and validated, using the secure multimedia conferencing application as a basis for demonstration. A Survivable Adaptive Planning Experiment (SAPE) is being initiated as a joint DARPA, Strategic Air Command (SAC), Rome Air Development Center (RADC) and the Joint Strategic Target Planning Staff (JSTPS) to develop survivable adaptive network technology; demonstrate critical elements of a survivable strategic C3 environment; and demonstrate a rapid adaptive strategic mission planning capability operating in that environment.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: # IC-2
Program Element: #62708E
USDR&E Mission Area: 530

Title: Advanced Command Control Communications Technology
Title: Integrated Command and Control Technology
Budget Activity: 1 Technology Base

2. Program Accomplishments and Future Programs:

a. FY 1988 Accomplishments: Access was provided to several semiconductor processes including 3-micron Complementary Metal Oxide Semiconductor (CMOS) and 1.2 micron CMOS. Research was initiated to provide rapid part procurement in a Metal Oxide Semiconductor Implementation System (MOSIS) like environment. A program was established to develop a high level Very Large-Scale Integrated Circuit (VLSIC) design system that uses application-specific silicon compliers to quickly design complex circuits. A computer-aided fabrication system has been implemented in the MIT fabrication facility and is in daily use. A process design workstation system was developed at MIT to permit rapid easy development of VLSI fabrication processes. Stanford University has implemented a MOSIS compatible CMOS process in its facility and a prototype process specification language in Common LISP. The development of the testbed for large scale networks continued. The interim versions of the testbed software was designed, tested and installed in testbeds at Fort Bragg and SAC HQ (Strategic Air Command Headquarters). Software development to support large survivable networks was initiated. Detailed design of algorithms and packet formats was begun. A study of the security requirements was also begun. Multiple contracts were awarded for preliminary designs to support the Multiple Satellite System. Several distributed command and control application demonstrations were developed in the Army/DARPA Distributed Communication and Processing Experiment (ADDCOMPE) testbed, including automated message generation and distribution, maneuver planning and control, fire support, and tactical communications network monitoring and reconfiguration. Multimedia conferencing prototype systems were implemented on the basis of existing DARPA-developed multimedia mail systems.

b. FY 1987 Program: The Metal Oxide Semiconductor Implementation System (MOSIS) will continue to accept research designs and to provide Complementary Metal Oxide Semiconductor (CMOS) fabrication services for the U.S. research and education community. A cell library is being established to facilitate new designs. Under a joint program with NSF, a new streamlined service is being implemented to provide fabrication to U.S. university classes at costs appropriate to lab fees. An extension to the MOSIS system is being prototyped to enable easy, rapid and inexpensive

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: # IC-2
Program Element: #62708E
USDR&E Mission Area: 530

Titie: Advanced Command Control Communications Technology
Titie: Integrated Command and Control Technology
Budget Activity: 1 Technology Base

acquisition of electronic components. A high levei design system is being prototyped in a government installation, and then will be avaiiabie for instaiiation in other sites. MOSIS is exploring the technical feasibility of offering eiectricaliy-eraseable prototyping service using their standard 3 micron vendors. The Massachusetts Institute of Technology Computer-Aided-Fabrication system is being extended to interface with several fabrication equipments in order to automate certain pieces of the process. A major new effort has been initiated at Stanford University for an object-flow approach to computer-integrated design, manufacture and test. The initial effort for this year is specifying the interface protocol with the users and with the various vendors. After formalizing the protocol, a manuai system will be installed where users communicate with the system via electronic mail. Existing commercial data bases for electronic parts are being acquired; and, users are being provided with virtual access to these data bases via the maii system. Tools are being developed to support the function that an Item Manager wouid perform in accessing these data bases. The results of the final system demonstration for the Strategic C3 experiment was evaluated and documented. A survivable, adaptable network testbed is being installed in the Fort Bragg and Strategic Air Command Headquarters (SAC HQ) testbeds. Experimentation with techniques improving survivablity and security are beginning. Preiiminary designs for the Multipie Sateiiite System are being completed and requests for proposals to build a prototype system are being released to industry. The Army/DARPA Distributed Communication and Processing Experiment (ADDCOMPE) distributed command and control applications are being evaiuated and evolved with continuous feedback from Army users in the Fort Bragg and other testbeds. Solutions to the tacticai end-to-end security problem are being developed in cooperation with the Army and the Nationai Security Agency. A protocoi suite to support multimedia conferencing over the Internet is being specified and tested. Methods and tools for specifying and developing very iarge C3 systems by evolution and assimilation are being defined and tested, using the multimedia conferencing appiication as a basis for demonstration. An architecture and devices for ensuring privacy of muitimedia conferences in very large C3 systems are being developed as a means for exploring distributed systems security architectures. Equipment remaining in place at SAC from the Strategic C3 Experiment is being augmented with additional equipment to build a testbed of internetworked processing eiements for the Survivable Adaptive Planning Experiment

Project: # IC-2
Program Element: #62708E
USDR&E Mission Area: 530

Title: Advanced Command Control Communications Technology
Title: Integrated Command and Control Technology
Budget Activity: 1 Technology Base

(SAPE). Utility programs and a distributed operating system for the Internet are being integrated into this testbed to provide automated resource management, data distribution, and failure recovery for distributed command and control applications in the future. Initial design is beginning on software systems to facilitate adaptive strategic mission planning, using recent advances in machine intelligence and user interface technology. Airborne link test is being performed of a survivable high bandwidth communications capability based on packet switching nodes aboard long-endurance airborne platforms.

c. FY 1988 Planned Program and Basis for FY 1988 Request: The Metal Oxide Semiconductor Inplementation System (MOSIS) will continue to provide access to a spectrum of semiconductor processes from 3 micron geometries down to 1.2 microns and to include other technologies such as Gallium Arsenide (GaAs) and Wafer-Scale Integration (WSI). Extensions to the MOSIS system for the acquisition of mechanical components and assemblies will be investigated. Foundry automation methods will be developed for the integration of advanced semiconductor manufacturing equipment and the computing and software systems needed to model and control semiconductor processes. A survivable, adaptable network testbed will continue to be developed in the Fort Bragg and SAC HQ testbeds. Experimentation with techniques improving survivablity and security will continue. Preliminary designs for the Multiple Satellite System will be completed and a prototype system will be developed. The ADDCOMPE (Army/DARPA Distributed Communication and Processing Experiment) distributed command and control applications will continue to be evaluated and evolved with continuous feedback from Army users in the Fort Bragg and other testbeds. Solutions to the tactical end-to-end security problem will continue to be developed in cooperation with the Army and the National Security Agency. A protocol suite to support multimedia conferencing over the Internet will be further developed and tested. Methods and tools for specifying and developing very large C3 systems by evolution and assimilation will be defined and tested, using the multimedia conferencing application as a basis for demonstration. An architecture and devices for ensuring privacy of multimedia conferences in very large C3 systems will be developed as a means for exploring distributed systems security architectures. Utility programs and an Internet distributed operating system will continue to be

Project: # IC-2
Program Element: #62708E
USDR&E Mission Area: 530

Title: Advanced Command Control Communications Technology
Title: Integrated Command and Control Technology
Budget Activity: 1 Technology Base

integrated into testbeds to provide automated resource management, data distribution, and failure recovery for distributed command and control applications. Development of Software systems to facilitate adaptive strategic mission planning will start. Projects in support of the U.S. participation in the Battlefield Information Collection and Exploitation Systems (BICES) will be pursued. Assessment and trade off of development options for this technically complex and politically sensitive system of national and NATO systems will be made, including the evolution of intelligence systems interoperability and harmonization of national and NATO intelligence architectures. Candidate BICES projects include development of a NATO Secret-level intelligence correlation network between France, Germany, Italy, United Kingdom and the U.S.; development of a Multilevel Secure Gateway to sanitize intelligence of different classification levels; establishment of systems linkages between the NATO Marltime Opintel Support (NMOS) and the Air Command and Control System (ACCS); development of multinational intelligence data exchange standards; and development of harmonized NATO and national intelligence architectures.

d. FY 1989 Planned Program and Basis for FY 1989 Request: Metal Oxide Semiconductor Implementation System (MOSIS) will start offering prototyping services for sub-micron technologies. Rapid system prototyping services will be made available that will enable the research community to move quickly from concept to system level demonstration. A survivable, adaptable network testbed will continue to be developed in the Fort Bragg and SAC HQ (Strategic Air Command Headquarters) testbeds. Experimentation with techniques improving survivability and security will continue. Preliminary designs for the Multiple Satellite System will be completed and a prototype system will be developed. The Army/DARPA Distributed Communication and Processing Experiment (ADDCOMPE) distributed command and control applications will continue to be evaluated and evolved with continuous feedback from Army users in the Fort Bragg and other testbeds. Solutions to the tactical end-to-end security problem will continue to be developed in cooperation with the Army and the National Security Agency. A protocol suite to support multimedia conferencing over the Internet will be further developed and tested. Methods and tools for specifying and developing very large C3 systems by evolution and assimilation will be defined and tested, using the multimedia conferencing

Project: # IC-2
Program Element: #62708E
USDR&E Mission Area: 530

Title: Advanced Command Control Communications Technology
Title: Integrated Command and Control Technology
Budget Activity: 1 Technology Base

appiication as a basis for demonstration. An architecture and devices for ensuring privacy of multimedia conferences in very iarge C3 systems wiil be deveioped as a means for exploring distributed systems security architectures. Utility programs and an Internet distributed operating system wiii continue to be integrated into testbeds to provide automated resource management, data distribution, and failure recovery for distributed command and control applications. Software systems to faciiitate adaptive strategic mission planning will add maturing machine intelligence and user interface technologies. Battiefieid Information Collection and Expioitation Systems (BICES) projects initiated in FY 1988 wiii continue in FY 1989.

e. Program to Completion: The Metai Oxide Semiconductor Implementation System (MOSIS) will continue to provide access to advanced semiconductor processing in support of the U.S. research community. Application of the MOSIS system will be extended to the prototyping and demand production of semiconductor components for defense agencies and contractors. The use of electronic mail in support of logistics appiications will be extended to incorporate the demand manufacturing of eiectrical and mechanical components and assemblies. Computer integrated manufacturing methods will be applied to semiconductor manufacturing testbeds and extended to other manufacturing technologies. Advanced high ievei design will be test-bedded at the Federal Bureau of Investigation (FBI) and made availabie to other government installations. A network management system for large scale survivable networks wiil be deveioped and evaiuated. Position iocation and end-to-end security capabilities wiil be integrated into the network. Multiple Satellite System prototype components wiii be tested on air frames. Prototype systems will integrated and impiemented Distributed command and controi experiments in the Fort Bragg and other Army testbeds will be completed, evaluated, and transferred to the Army. An evoiutionary systems deveiopment method and toolset for very iarge C3 systems wiii be demonstrated and vaiidated, using secure multimedia conferencing in cooperation with one or more of the Services as a basis for demonstration. A highiy survivable wide-area high bandwidth data communication system wiii be deveioped and empioyed in support of the Survivabie Adaptive Planning Experiment (SAPE). An intelligent muitiband controller will be demonstrated which adaptiveiy seiects among various communication channeis and media to maximize communications reliability. Command and

Project: # IC-2
Program Element: #62708E
USDR&E Mission Area: 530

Title: Advanced Command Control Communications Technology
Title: Integrated Command and Control Technology
Budget Activity: 1 Technology Base

control experiments will be conducted to exercise a rapid adaptive strategic mission planning capability whose components are replicated and distributed to provide trans- and post-attack endurance. New machine intelligence techniques will be used to develop an "intelligent platform network," which uses autonomous control of airborne communications platform position to adaptively maximize network connectivity.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestone
Early FY 1987	Early FY 1987	Develop method for evolutionary development of very large C3 systems.
Mid FY 1986	Mid FY 1987	Integrate security devices into packet radio networks at Ft. Bragg and SAC (Strategic Air Command).
Mid FY 1986	Mid FY 1987	Initial low-cost packet radios (LPRs) delivered to testbeds.
- -	Mid FY 1987	Automated acquisition of electronic parts demonstrated.
Late FY 1987	Late FY 1987	Demonstrate command and control simulator network.
Mid FY 1988	Mid FY 1988	Demonstrate large-scale survivable network.
Mid FY 1988	Mid FY 1988	Demonstrate low-cost multi-satellite communication in the laboratory.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: # IC-2
Program Element: #62708E
USDR&E Mission Area: 530

Titie: Advanced Command Control Communications Technology
Titie: Integrated Command and Control Technology
Budget Activity: 1 Technology Base

Last Year's Reported Plan	Current Plan	Milestone
Mid FY 1988	Mid FY 1988	Airborne iink testing of survivabie communication system compieted.
Mid FY 1987	Late FY 1988	Large numbers of LPRs deiivered to testbeds.
Late FY 1988	Late FY 1988	Internet distributed operating system demonstrated in Survivable Adaptive Pianning Experiment (SAPE) testbed.
- -	Mid FY 1989	High-ievei design system avaiiabie to government instaiiations.
Late FY 1988	Late FY 1989	Airborne demonstration of Muitiple Sateiiite concept.
Late FY 1989	Late FY 1989	Sub-micron prototyping services avaiiabie through Metai Oxide Semiconductor Impiementation System (MOSIS).
Late FY 1989	Late FY 1989	Begin fuii system demos of survivabie communications using high bandwidth packet switches on iong endurance airborne piatforms.
Late FY 1990	Late FY 1990	Demonstrate integrated survivabie adaptive pianning capabiiity.
Mid FY 1992	Mid FY 1992	Demonstrate inteiiigent airborne piatform network.

g. Explanation of Milestone Changes: Fauits in the hardware technology have delayed NSA certification, and integration into testbeds of security devices (IPLIs). The deveiopment and deiivery of iow-cost packet radios (LPRs) has siipped due to funding constraints, programmatic

Project: # IC-2
Program Element: #62708E
USDR&E Mission Area: 530

Title: Advanced Command Control Communications Technology
Title: Integrated Command and Control Technology
Budget Activity: 3 Technology Base

realignments, and hardware problems in security devices. Airborne demonstration of the Multiple Satellite concept has been delayed based on more extensive planning.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62712E
USDR&E Mission Area: 530

Title: Materials and Electronics Technology
Budget Activity: 1. Technology Base

A. RESOURCES (PROJECT LISTING): ($ in Thousands)

Project Number	Title	FY 1986 Actual	FY 1987 Estimate	FY 1988 Estimate	FY 1989 Estimate	Additional to Completion	Total Estimated Costs
	TOTAL FOR PROGRAM ELEMEN	$23,032	$27,920	$27,606	$26,700	Continuing	N/A
MPT-1	Materials Processing Technology	$19,562	$22,870	$18,606	$19,200	Continuing	N/A
MPT-2	Electronics Processing Technology	$ 3,470	$ 5,050	$ 9,000	$ 7,500	Continuing	N/A

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This program element develops novel materials, processes, structures and device technologies that will give new capability to future defense weapon systems. Examples are: application of advanced intermetallic composites to enable higher temperature operation of gas turbine engine components; development of ceramic matrix and carbon/carbon composites for high temperature structural applications; advanced fabrication methods for structural materials; metal-matrix and carbon-carbon composites for space structures; strong ceramic fibers from polymer precursors for aerospace structural and propulsion components; intelligent materials processing; and intelligent task automation aimed at establishing the technology base for advanced sensory controlled robotic systems. In electronics, the emphasis is on the development of heterojunction technology, maskless processing for submicron structures, and high density packaging technology for high performance military systems.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #62712E
USDR&E Mission Area: 530

Title: Materials and Electronics Technology
Budget Activity: 1. Technology Base

C. COMPARISON WITH FY 1987 DESCRIPTIVE SUMMARY: The decrease of $2.4M in FY 1987 and $9M in FY 1988 in MPT-1 is caused in part by the successful completion of a large program on producing strong ceramic fibers from polymer precursors and completion of a major activity demonstrating the performance of a dual alloy radial turbine rotor in a simulated turbine environment. Fiscal constraints will delay initiation of several new starts in carbon-carbon composites research. The decrease of $4.4M in FY 1987 and $5M in FY 1988 in MPT-2, Electronic Processing Technology is accommodated by terminating all efforts in digital gallium arsenide circuit development. As much as possible the successful efforts in this area have been transferred to the DARPA managed Strategic Defense Initiative Organization (SDIO) effort in Radiation Hardened, Very Large Scale Gallium Arsenide Integrated Circuits.

D. OTHER APPROPRIATION FUNDS: None.

E. RELATED ACTIVITIES: In MPT-1, carbon-carbon research and development programs are currently underway at the National Aeronautics and Space Administration (NASA) (for airframes) and the Air Force Materials Laboratory (AFWAL) with the goal of 1370°C turbine inlet temperature operation. Additionally, modified carbon-carbon is under consideration by the Strategic Defense Initiative Office for application in the boost phases of ballistic missiles. Programs to develop high performance ceramic materials for gas turbine engine components are being conducted by all the Services, NASA, and the Department of Energy; plans and programs are reviewed by an Interagency Ceramics Coordinating Committee. The ceramic fibers from polymer precursors program is reviewed by an interagency steering committee established by DARPA for that purpose. Generally, the Services are sponsoring research related to unique manufacturing methods which are different than those being pursued by DARPA, and duplication of effort is prevented by direct coordination through the Office of Under Secretary of Defense for Acquisition (OUSD(A)), the Manufacturing Technology Advisory Group (MTAG),COMAT, which is a committee under the aegis of the White House Office of Science and Technology Policy, and the Interagency Materials Group which is hosted by the National Science Foundation. The intelligent task automation program is related to, complemented by and coordinated with efforts by the Air Force Wright Aeronautical Laboratories, the National Bureau of Standards, Army Research Office, Office of Naval Research, and the Army Laboratory Command. In MPT-2, developments in electronic materials, device concepts, and processing methods are coupled to the

services' programs through the DARPA agents, joint funding agreements, annual DoD-wide program reviews, and reviews with OUSD(A)'s Advisory Group on Electron Devices (AGED), to assure that no unnecessary duplication of effort occurs.

F. WORK PERFORMED BY: In MPT-1, approximately 60% of the work is performed by industry, 20% universities, 10% foreign, and 10% in-house. The top industrial performers (including foreign) are: Kongsberg Vaapenfabrikk, Oslo, Norway; General Electric Corporation, Schnectady, New York; Dow Corning Corporation, Midland, Michigan; United Technologies Research Center, East Hartford, Connecticut; Union Carbide, Parma, Ohio; and Martin Marietta Aerospace, Denver, Colorado. The universities include: Massachusetts Institute of Technology, Cambridge, Massachusetts; University of Texas, Austin, Texas; Stanford University, Palo Alto, California. The Naval Research Laboratory, Washington, D.C., Air Force Materials Laboratory, Dayton, Ohio; and Naval Air Development Center, Warminster, Pennsylvania perform in-house research.

In MPT-2, approximately 63% of the work is performed by industry, 30% by universities, 5% by FCRCs and 2% in-house. The top performers are: Varian, Palo Alto, California; Texas Instruments, Dallas, Texas; MIT Lincoln Laboratory, Lexington, Massachussetts; and Stanford University, Palo Alto, California.

G. PROJECTS UNDER $7 MILLION IN FY 1988-1989: Not Applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: MPT-1
Program Element: #62712E
USDR&E Mission Area: 530

Title: Materials Processing Technology
Title: Materials and Electronics Technology
Budget Activity: 1. Technology Base

B. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The objective of this project is to develop a variety of material systems and processes for use in high performance DoD applications. The specific programs include: the development of advanced composite materials such as metal matrix, ceramic matrix and carbon-carbon composites; the processing of ceramic fibers and whiskers; the fundamental characterization of carbon-carbon processing; intelligent task automation aimed at establishing the technology base for advanced sensory controlled robotic systems; the development of a DARPA dual alloy radial turbine engine (DART) demonstrator for testing and demonstration of high temperature structural materials under realistic gas turbine conditions; and intelligent processing of materials, a revolutionary approach to improve the way in which materials are made and to accelerate their transition from research and development into production.

DARPA has pioneered ceramic matrix and carbon-carbon composites for turbines and other advanced power plants because these materials promise engine designs with reduced weight, increased performance, reduced dependence on costly and critical alloy materials, and the lower specific fuel consumption gained by operation at high temperatures. An effort is being undertaken to develop a coating system for carbon-carbon composites which will permit their use in engines at temperatures in excess of 1930°C. The technology for obtaining oxidation resistant ceramic fibers and ceramic matrix composites is also underway. The ceramic composites being developed will offer high strength, laser resistant and fracture resistant materials for a wide range of applications including spacecraft structures and power systems, engine components, armor, infrared windows and composite gun barrel liners.

The intelligent task automation program is aimed at establishing the technology base for advanced sensory controlled robotic systems.

A program of experimental work has been initiated to determine the critical processes in

carbon-carbon processing to achieve higher strength and improved fabrication capability. The basic information on process variables and composite formulation will be utilized immediately in the intelligent carbon-carbon processing program.

Research in metal matrix composites focuses on novel processing methods to attain in-situ reinforcing particulates and filaments in metallic matrices for high temperature high specific strength and modulus materials requirements, including structural components for hypersonic vehicles. Specific applications include those where multifunctional capabilities such as high strength and electrical and thermal conductivity (e.g., rocket engines and electromagnetic launchers) are needed.

The intelligent processing of materials is a program in which sophisticated process models and in-situ, real time sensors are being developed and combined with artificial intelligence approaches to control the way in which structural and electronic materials are processed.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: In the ceramics from polymers effort, a detailed study of the causes of thermal instability in ceramic fibers led to changing some fiber compositions. This should lead to fibers having stability significantly better than the current state-of-the-art Japanese fibers. Fiber strengths of 450Ksi and moduli of 30MSI have been achieved in multifilament fiber tows. Ceramic matrix composites with high strength and toughness also were demonstrated in this program. In the effort to scale-up the production of silicon carbide whiskers, process improvements in the laboratory scale reactor showed initial success. Some later difficulties in design were encountered which caused delays in scale-up.

In the effort to develop oxidation protection for carbon-carbon composites, two coating concepts, one based on silicon nitride and the other on a metal-based system, have been selected for further development. These coating systems provide oxidation protection to 1760°C and 1925°C, respectively, with good adherence to the substrate. The DARPA Dual Alloy Radial Turbine (DART) demonstrator engine has been

successfully fabricated and performance testing is now underway. The engine has achieved shaft rotational speeds at 85,000 rpm, about 90% of its rated capability, without major problems.

In the intelligent task automation program the feasibility of constructing a system to assemble a small complex electro-mechanical device automatically from a kit of parts was demonstrated. This robotic system will identify the parts visually, assemble the parts under visual and tactile control, and inspect the assembly visually. Detailed design was started on a second robotic system capable of planning and performing assembly and inspection tasks. Electrostatic forces were applied to the control of movement of a fiber-optic electret. The scientific principles applied in this device may lead to a new class of high-performance sensors and actuators.

Metal matrix composite research included studies on graphite/magnesium composites for space structures which require zero coefficient of thermal expansion and high specific strength and modulus in tubular members and structural joints. The technology for producing these composites was further refined by improving casting processing conditions. Cast composite tubing (3 feet long and 2 inch diameter) has been produced. A program to examine the strengthening mechanisms of high thermal conductivity fiber reinforced composites for propulsion systems was continued.

A program in electromagnetic processing of materials utilized various electromagnetic energy sources for improved processing of structural materials having limitations in production that degrade performance. Sources of extremely high current such as in a homopolar generator were demonstrated to sinter refractory molybdenum metal powders.

b. FY 1987 Program: The structural ceramics effort continues to develop and test ceramics and ceramic composites for applications in high temperature gas turbine engines, radar absorbing structures, and armor applications. Fibers with increased thermal stability are being produced and incorporated into ceramic matrix composites. The ceramic fibers from polymer precursor effort is being completed and transitioned to the Air Force.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: MPT-1
Program Element: #62712E
USDR&E Mission Area: 530

Title: Materials Processing Technology
Title: Materials and Electronics Technology
Budget Activity: 1. Technology Base

An on-going effort is evaluating the state-of-the-art in ceramic composites for their applicability to small, lightweight gas turbine engines. In a program begun late in FY 1985, the use of ceramics as erosion resistant, lightweight liners for gun barrels, is being examined by establishing designs and preparing materials for testing. The process improvements in the whisker growth program are being incorporated into the pilot plant reactor to get the yield up to desired quantities and quality. At present experimental difficulties in scaling up the process are being encountered.

The next phase of the carbon-carbon composites oxidation protection program entails further development of the silicon nitride and iridium-based systems, which have shown superior performance. Turbine rotor subelements of carbon-carbon, appropriately coated with the protective systems, are being tested at elevated temperature within a combustion gas environment duplicating that of an operating turbine engine.

The DARPA Dual Alloy Radial Turbine (DART) Demonstrator turbine engine will be further exercised to its maximum operating speed of 93,000 rpm, while being carefully monitored for new vibration modes. The dual alloy turbine rotor is being installed for final testing, including a 50-hour endurance test which will cycle the rotor to various temperature levels under load. Efforts in the vacuum arc double electrode remelt (VADER) process is being concluded. Delays in technology transfer to a planned Air Force/Army joint effort for turbine superalloys are being encountered due to funding limitations.

In the effort to determine the fundamentals of carbon-carbon composites processing, matrix and fiber constituent materials are being modelled according to current information on their structure and chemistry. The role of matrix precursor chemistry has been elucidated, and the processability ranges have been extended based on new information. In-situ studies of fiber and matrix materials are continuing.

In the intelligent task automation program, two robotic systems are being designed to demonstrate the integration of robotic technology. One system is being demonstrated in the inspection of an F-15 bulkhead. System integration is being started on the other robot, which will be demonstrated in the assembly of a microswitch from the switch's parts dumped on a tray. Work is starting on an advanced robotic manipulator with approximately anthropomorphic performance and incorporating advanced mechanical,

sensor, and control technologies. Research is continuing on the application of electrostatic forces to sensing and actuation.

Efforts in the intelligent processing of materials are continuing to establish the sensor and process models which are needed. An architecture for the artificial intelligence control scheme is being designed and constructed. A new effort in intelligent growth of bulk single crystal gallium arsenide is being initiated with the goal of increasing dramatically the yield of high quality crystals for microelectronics applications. A new effort to achieve intelligent processing of carbon/carbon composites is also being initiated.

c. FY 1938 Planned Program and Basis for FY 1988 Request: Current ceramic and ceramic composite research with applications of interest to DoD such as high temperature engines, radar absorbing materials and armor will be transitioned to Service Man-Tech programs. The effort to evaluate ceramic composites for engines will continue. The output of this program should provide incentives for transition to the services of the composites developed in the ceramics from polymers program. The ceramics for gun barrel liners effort will conclude with the testing of ceramics in both single shot and multiple shot firings.

Evaluation of carbon-carbon composites oxidation protection systems will continue by extending the capability of the coating system to three-dimensional carbon-carbon architectual designs currently being fabricated.

A rotor subelement with oxidation protection will be designed, fabricated and tested in a hot spin rig where the component temperature reaches 1930°C in a combustion gas environment.

The DARPA Dual Alloy Radial Turbine (DART) Demonstrator turbine engine will be installed in a test cell facility at the Naval Air Propulsion Center for utilization in a program of advanced composites development. It is intended that this will be a cooperative activity under the auspices of a joint agreement made with the government of Norway.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: MPT-1
Program Element: #62712E
USDR&E Mission Area: 530

Title: Materials Processing Technology
Title: Materials and Electronics Technology
Budget Activity: 1. Technology Base

In the investigation of the fundamentals of carbon-carbon composite processing, previous work on the characterization of fiber and matrix materials will be extended to unidirectional composites. First, models will be developed relating mechanical responses to basic fiber/matrix properties, and second, procedures will be developed for preparing carbon-carbon composites and measuring their thermophysical properties.

In the intelligent task automation program, the demonstration of the robotic systems currently being developed to integrate advanced robotic technology into assembly and inspection will be accomplished. The project to develop an advanced robotic manipulator with approximately anthropomorphic performance will be 50% completed. New projects will be started to develop and demonstrate the technologies required for high performance and intelligent robotic systems for both field and manufacturing application. Emphasis will be on the technologies required for autonomous operation of the robotic systems.

In the intelligent processing of materials program, an effort will begin to incorporate sensors and models into the artificial intelligence framework. The development of an expert system in a representative material process for gallium arsenide bulk single crystal growth will be demonstrated. An effort on intelligent control of chemical vapor infiltration of ceramic matrix composite turbine components will be initiated.

In the electromagnetic processing program, optimization of pulsed power from very high power systems will occur, which will lead to future activities to consolidate refractory metals and intermetallic powders for high temperature structural applications.

Intermetallic metal matrix composite processing routes will be more firmly established for formation of in-situ and hybrid reinforcements which control strength, modulus, and creep in propulsion and other air vehicle structures exposed to high temperatures.

d. FY 1989 Planned Program and Basis for FY 1989 Request: Research will continue to develop new processing approaches for fabricating superior high temperature structural composites.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: MPT-1
Program Element: #62712E
USDR&E Mission Area: 530

Title: Materials Processing Technology
Title: Materials and Electronics Technology
Budget Activity: 1. Technology Base

Intelligent materials processing of gallium arsenide crystal growth, carbon-carbon composite fabrication, and chemical infiltration of composites will demonstrate the feasibility of incorporating artificial intelligence, expert systems, and real time sensing in materials processing.

In the intelligent task automation program, the development of an advanced robotic manipulator with approximately anthoropomorphic performance will be nearly completed. Other major demonstration projects and specific technology projects will be directed toward high performance and intelligent robotic systems for both field and manufacturing application.

e. Program to Completion: This is an on-going project which will continue to assess DoD materials needs and to develop and demonstrate novel concepts to meet them. Some specific efforts which will be completed and/or transitioned are described below.

Selected ceramic fibers and ceramic matrix composites will be optimized and evaluated for applications of interest to DoD such as radar absorbing materials or space power structural components. Having achieved a basic understanding of the processing and oxidation protection of carbon-carbon composites, a renewed effort will be made to introduce better carbon-carbon composites - from the point of view of capability and characterization - into critical portions of high-performance aerospace systems.

In the intelligent processing of materials program, efforts will continue to address the key issues leading to the demonstration of the concept, including the knowledge acquisition process to efficiently incorporate the knowledge of both laboratory and shop floor experts into production control.

f. Milestones: The milestones reported in the FY 1987 Descriptive Summary have been completed or are expected to be completed on schedule.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: MPT-1
Program Element: #62712E
USDR&E Mission Area: 530

Title: Materials Processing Technology
Title: Materials and Electronics Technology
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestones
Early FY 1987	Early FY 1987	Demonstration of capability of producing graphite/magnesium zero coefficient of thermal expansion composites for space structures via a prototype space structure.
Late FY 1987	Late FY 1987	Delivery of completed and tested DARPA/DART Demonstrators to U.S. locations.
Late FY 1988	Late FY 1987	Demonstration of prototype rocket nozzle materials based on in-situ reinforced ultra-fine composites with high thermal conductivity.
--	Mid FY 1988	Demonstrate cooperative manipulation of objects by two flexible robotic arms.
--	Mid FY 1988	Initiate a program for testing carbon-carbon and ceramic components within the DARPA Demonstrator facility at Naval Air Propulsion Center.
--	Early FY 1989	Demonstration of the intelligent process control concept in production of gallium arsenide single crystals.
--	Mid FY 1990	Demonstrate robotic manipulator arm with approximately anthoropomorphic capabilities.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: MPT-1
Program Element: #62712E
USDR&E Mission Area: 530

Title: Materials Processing Technology
Title: Materials and Electronics Technology
Budget Activity: 1. Technology Base

g. Explanation of Milestone Changes: None.

I. TEST AND EVALUATION DATA: Not Applicable.

J. COOPERATIVE AGREEMENTS: Not Applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #MPT-2
Program Element: 61101E
USDR&E Mission Area: 530

Title: Materials Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: This project [illegible]s heterostructure development for high performance circuits, process modelling for compound semic[illegible]ors, development of technology for tenth-micron-resolution semiconductor processing, and developm[illegible] of high density packaging technology for multiprocessors to be used in a new generation of compact "smart weapons" systems. The near-term emphasis is on the development of high-efficiency solar cells, heterostructure growth, and utilization of ion beams for device fabrication. Process and device modelling programs will be expanded to provide increased support to the integrated-circuit design and fabrication programs.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: The transient radiation-hardened complementary junction field-effect transistor (CJFET) program has been successfully concluded. The location of circuit nodes that are prone to single event upset was identified by electron-beam probing, and hardening techniques were incorporated into the final design that eliminated failure at these locations.

Using a new optical technique, Lincoln Laboratory researchers have attained lithographic dimensions on the order of 0.15 micron, which is five times better than that of refined optical lithographic systems ("wafer steppers") and is superior to current practical e-beam and x-ray lithography methods. The technique uses deep-ultraviolet excimer lasers in a configuration similar to a conventional "wafer stepper" exposure system.

The development of a process model for gallium arsenide (GaAs) microcircuits started with investigations of ion-implantation activation and diffusion. The process model previously developed for silicon microcircuits is used by virtually every defense and commercial circuit manufacturer in the United States.

Project: #MPT-2
Program Element: 61101E
USDR&E Mission Area: 530

Title: Materials Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

b. FY 1987 Program: A process model, with the end goal of producing a gallium arsenide (GaAs) version of the Stanford University Process Emulation Model (SUPREM), is being released in its initial version to users. Individual cells of a 30%-efficient cascade solar cell will be optimized to achieve the required efficiency of each part; efforts are underway to combine these individual cells via graded transition layers. A computer-aided design (CAD) system for GaAs gate arrays is being released to initial test sites. The program is a collection of individual design tools tightly integrated through a common database for the design of signal processors that are implemented with semi-custom integrated circuits.

The capability to use focused beams of electrons, photons, and ions to locally modify integrated circuits is being continued by the design and fabrication of sophisticated novel devices and large scale integrated circuit components featuring patterns having geometries smaller than 500 nanometers.

Research efforts in high density chip packaging technology are being initiated. The overall goal is to demonstrate the feasibility of achieving one billion floating point operations per second (GFLOPS) and four Giga-bytes within 100 cubic inches, and implementing it economically by mass production means. The work encompasses both high density memory and generic packaging efforts for logic. Initially very large scale integrated, (VLSI) chips are being interconnected in order to demonstrate the packaging of a 25 megahertz silicon processor and its associated memory. Extensive thermal, electrical, and mechanical testing is being performed. Fault detection, isolation, and repair is being demonstrated.

The work in biotechnology, which was addressed in this project in last year's descriptive summary, is now being accomplished in the 61101E program element (project DRH-1).

c. FY 1988 Planned Program and Basis for 1988 Request: Device development efforts in heterostructure, high-speed gallium arsenide (GaAs) device technology and process modelling will continue. Basic materials and processing improvements that were achieved in prior years' work under the 61101E program element will be incorporated into practical device and integrated-circuit structures to demonstrate useful components. A 30% efficiency heterojunction solar cell will be demonstrated. The

gallium arsenide (GaAs) version of the process modelling program will provide one-dimensional impurity distributions as inputs to device design programs. High density packaging efforts will continue. The generic interconnection approaches will be modified so as to demonstrate the packaging of a silicon processor and its associated memory running at speeds of 40 megahertz. The high density memory interconnect scheme will be optimized and scaled up, and work started on the fabrication and assembly of a sufficient number of modules to demonstrate the four Giga-Byte goal.

Efforts to use focused electron, photon and ion beams to locally modify integrated circuits will continue with an emphasis on the integration of all three beam processing technologies into a single enclosure, integrated circuit fabrication module. This goal will provide a means to eliminate circuit defects caused by ultrasmall contaminant particles, as well as an efficient means to fabricate and repair in realtime complex integrated circuits.

Work will begin on the development of a new optical storage technology which could provide millisecond access to 500 gigabytes of on-line storage with data rates of 5 megabits per second. This will be accomplished by the three dimensional storage of an array of one-micron sized spots within a 16 cubic inch photopolymer storage block.

d. FY 1989 Planned Program and Basis for FY 1989 Request: Work will begin on the fabrication and demonstration of a distributed multi-sensor/processor system, linked together in a reconfigurable fiber optic network. The objective would be to show not only the ability to rapidly reconfigure, but would show the ability to process (including fusing and compacting) data from a wide variety of sensor types.

Realization of heterostructure integrated circuits that utilize devices made monolithically in more than one material will begin. Initial efforts will concentrate on laser readout of both silicon and heterojunction circuits.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: MPT-2
Program Element: 61101E
USDR&E Mission Area: 530

Title: Materials Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

The packaging of a 200 MHz gallium arsenide (GaAs) processor will begin using government-supplied GaAs chips. Multiple high density memory modulus will be interconnected to begin the demonstration that the goal of 4 Giga-Bytes can be achieved.

e. Program to Completion: This effort is a continuing one due to the exceptional importance of information and signal processing capabilities to defense systems. While initial gallium arsenide (GaAs) developments have emphasized radiation hardness, the heterojunction technology will be applied to high-speed DoD needs in electronic warfare.

Opto-electronic processing capability will be advanced to develop concepts in which electronics handles the switching and optics handles the high speed transfer of multiplexed data. This program will develop the packaging technology necessary to incorporate this emerging capability into subsystems which can benefit from the noise immunity, wide bandwidth, Electro-Magnetic Pulse (EMP) immunity, and the ease of fan-out offered by the optoelectronics.

The small, high density conventional packaging program will demonstrate a high density signal processing function in a volume that is appropriate to a smart projectile configuration

f. Milestones: The milestones reported in last year's FY 1987 Descriptive Summary have been completed or are expected to be completed on schedule except as noted below:

Last Year's Reported Plan	Current Plan	Milestones
--	Mid FY 1988	Demonstration of high density packaging with 25 megahertz silicon processor.
--	Mid FY 1988	Release of Version A of gallium arsenide process model to industrial users.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #MPT-2
Program Element: 61101E
USDR&E Mission Area: 530

Title: Materials Sciences
Title: Defense Research Sciences
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestones
Late FY 1987	Late FY 1988	A ring oscillator and a flip-flop will be designed and fabricated using the maskless focussed ion beam process.
	Late FY 1988	Thirty percent - efficient solar cell demonstration.
--	Early FY 1989	Demonstration of volume storage by the use of two-photon photochemistry activated with two different laser beams.
--	Mid FY 1989	Demonstration of high density packaging with 40 megahertz silicon processor.

g. Explanation of Milestone Changes: The start of the maskless focussed ion beam program was delayed one year due to funding reductions.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E Descriptive Summary

Program Element # 62714E
USDR&E Mission Area: 530 (TIARA)

Title: Nuclear Monitoring
Budget Activity: 1. Technology Base

A. RESOURCES ($ in Thousands)

Project Number	Title	FY 1986 Actual	FY 1987 Estimate	FY 1988 Estimate	FY 1989 Estimate	Additional to Completion	Total Estimated Costs
	TOTAL FOR PROGRAM ELEMENT	$17,550	$18,950	$20,363	$22,600	Continuing	N/A

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: The Nuclear Monitoring program conducts research and development to enhance U.S. capabilities for monitoring nuclear explosions. The program also provides technical information needed for developing sound national policy for negotiations on treaties limiting nuclear testing. It provides technical support for U.S. participation in the current negotiations with the Soviet Union and in treaty-related international activities. In the event that a Comprehensive Test Ban Treaty, or a low-level Threshold Test Ban Treaty, or step-by-step limits to testing were to be negotiated, U.S. security would require the highest possible level of monitoring capability to verify that the Soviets were complying with the provisions of such a treaty and not conducting clandestine tests under conditions designed to evade detection. In particular, better technical understanding is required to assess the the monitoring value of stations internal to the USSR, high frequency seismic wave propagation tion, yield determination at low thresholds, and on-site inspection procedures. The need for the nuclear monitoring program is further exemplified by the unexpected initiation of negotiations for an explosion yield threshold treaty in 1974, requiring the development (in a period of less than a year) of special monitoring provisions for the Peaceful Nuclear Explosion Treaty (PNET). The recent U.S. proposal for initiation of Nuclear Test Ban Talks in Geneva aimed at reducing the uncertainty surrounding the monitoring of the Threshold Test Ban Treaty yield limit and progressive limitations on nuclear tests has clearly brought to the forefront the need for an improved technical basis for monitoring. Both the Congress and the President have raised the possibility of U.S.-Soviet scientific cooperation and data exchange in this area. This research program continues to provide key technical support to U.S. efforts in the United Nations Conference on Disarmament; particularly in the development of an International Seismic Data Exchange System for global treaty monitoring. Other research efforts in this program are aimed at developing the sensors and advanced technology needed to detect the presence of nuclear materials at remote distances.

C. COMPARISON WITH FY 1987 DESCRIPTIVE SUMMARY: No significant changes. The FY 1988 request contains new emphasis on development of the U.S. portions of an international seismic data exchange system for which a global test is planned for FY 1988-89. Also emphasized is technical support to proposed negotiatons and possible scientific cooperation with the Soviets.

FY 1988-1989 RDT&E Descriptive Summary

Program Element # 62714E
USDR&E Mission Area: 530 (TIARA)

Title: Nuclear Monitoring
Budget Activity: 1. Technology Base

D. OTHER APPROPRIATION FUNDS: None.

E. RELATED ACTIVITIES: Complementary research is conducted by the National Laboratories of the Department of Energy and by the Air Force Technical Applications Center (AFTAC) for operational applications. These efforts are coordinated through existing interagency agreements and periodic working level coordination meetings.

F. WORK PERFORMED BY: Approximately 73% of this work is performed by industrial contractors, 18% in-house laboratories, 7% foreign, and 2% university. Major performers include: Teledyne Geotech, Garland, Texas and Alexandria, Virginia; S-Cubed, La Jolla, California; Lockheed Palo Alto Research Laboratory, Palo Alto, California; Science Applications International Corp., McLean, Virginia and San Diego, California; Science Horizons Inc., Encinitas, California; NTNF/NORSAR, Kjeller, Norway; the University of Florida, Gainesville, Florida; Columbia University, New York, New York; U.S. Geological Survey, Albuquerque, New Mexico; Sandia National Laboratories, Albuquerque, New Mexico, and Los Alamos National Laboratory, Los Alamos, New Mexico.

G. PROJECTS LESS THAN $7 MILLION IN FY 1988: Not Applicable.

FY 1988-1989 RDT&E Descriptive Summary

Program Element # 62714E
USDR&E Mission Area: 530 (TIARA)

Title: Nuclear Monitoring
Budget Activity: 1. Technology Base

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The program objective is to improve the U.S. capability in yield estimation of the nuclear tests of other nations, to improve the detection, location, and discrimination of earthquakes and explosions, and to improve the U.S. capability to detect and analyze nuclear radiation from materials (TIARA). This project provides the fundamental research and development which is required to demonstrate the detection of any nation's nuclear tests, and to accurately estimate their yields. The project also provides the scientific support to bilateral and international nuclear test ban efforts in which the U.S. is involved, such as those sponsored by the Conference on Disarmament and bilateral negotiations and technical exchanges with the Soviet Union.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: Yield Estimation. Laboratory experiments, finite difference calculations and analysis of field data improved our ability to predict coupling to and propagation of underground nuclear test energy in the earth, and to allow for effects of non-uniform propagation and of cratering. Methodologies for seismic yield estimation resulting in significant reductions in uncertainty were developed. These methodologies were applied to recalculate the yields of all Soviet tests leading to significant improvements in yield estimation at the 150Kt threshold.

Data Acquisition. Data from a high-frequency seismic array installed in Norway in a joint effort with the government of Norway was collected and analyzed. Preliminary research results indicate dramatic improvements in event detection and discrimination, especially of small events from the Soviet Union. Several long-term instrument development projects were completed. These new instruments can improve signal detection in noisy environments. Procedures for acquiring data from a network of stations installed in the People's Republic of China (PRC) with the cooperation of the PRC were established and data is being sent to the U.S. The data isexpected to improve our yield estimation and our discrimination capability.

Data Analysis. An evaluation for the applicability of knowledge based technologies was conducted with the Air Force. A prototype system for the analysis of data from multiple sensor systems was designed.

Program Element # 62714E
USDR&E Mission Area: 530 (TIARA)

Title: Nuclear Monitoring
Budget Activity: 1. Technology Base

A system was developed and delivered to Australia as part of a joint program with the Air Force. The system, for use by a host country; acquires and processes data from a seismic array in Alice Springs Australia. It is a model for all other AFTAC sites requiring distributed signal processing or host country data sharing.

Discrimination of Earthquakes from Explosions. Several promising new techniques to discriminate small magnitude events have been successfully applied to digital data from events which could not be otherwise identified. Theoretical and empirical studies continued on the difficult problem of regional discrimination. An empirical-statistical study was made of the hide-in earthquake evasion technique.

The final report was completed on a large global experiment conducted under the auspices of the United Nations, Conference on Disarmament (CD), to test and evaluate procedures to be employed by an International Data Exchange System. The report recommended major improvements to a future international monitoring system, especially the rapid exchange of raw waveform data.

Two space experiments for x-ray imaging and testing new gamma ray detector materials which were prepared for shuttle launch in early 1986 have been placed into long-term storage, pending resumption of shuttle service.

b. FY 1987 Program: Yield Estimation. Laboratory experiments and finite difference calculations are continuing in order to understand explosion energy coupling in jointed and fractured rock. The unified seismic method developed in 1986 to predict precise yields at a number of major Soviet Test Sites.
Test Sites will be transferred to the Air Force Technical Applications Center for operational use. Techniques for improved verification of lower yield thresholds will be investigated. Efforts will continue providing a technical basis for the ongoing talks on Nuclear Test limitations. Efforts are being applied to develop appropriate monitoring technologies applicable to a step-by-step limitation on nuclear testing, including reduced thresholds and numbers of tests.

Data Acquisition. Data from the small array in Norway (NORESS) will be analyzed with an emphasis on the detection of small explosions and on the reception of high frequency seismic waves which may be of use to detect decoupled explosions.

FY 1988-1989 RDT&E Descriptive Summary

Program Element # 62714E
USDR&E Mission Area: 530 (TIARA)

Title: Nuclear Monitoring
Budget Activity: 1. Technology Base

Data from large industrial chemical explosions in the USSR will be analyzed to develop techniques to distinguish them from nuclear events. A program will be initiated to design an advanced array signal processing system using Artificial Intelligence to assess the data from the array. The good of such a system will be its ability to automatically detect, locate and classify seismic events in the vicinity of the array down to a very small magnitude.

Discrimination of Earthquakes from Explosions. Laboratory and theoretical approaches to regional propagation, especially high-frequency propagation, are being emphasized in order to lay a firm foundation for empirical studies of discrimination and yield estimation. A careful study of empirical data on cavity decoupling is continuing. A study of discrimination between quarry blasts and earthquakes in the uniquely well instrumented area of San Francisco, California, is underway.

Support of International Negotiations. A new concept for an international monitoring system will be presented to the United Nations Group of Scientific Experts. Research studies will be conducted to provide a firm basis for estimating the verification capability international systems might provide, and the resources required to establish such systems. Initial experiments on the global exchange of large volumes of waveform data will be conducted using the facilities of the prototype international data center at the Center for Seismic Studies.

Nuclear Materials Detection (TIARA). Increased emphasis is placed on development and testing of sensors for nuclear materials detection. This focuses on a planned experiment for launch by Titan II. This experiment is ranked the number one priority by the Tri-Service Space Test Program Review Committee. Final design for both the space-borne imaging neutron detector array and the imaging, high-resolution gamma-ray detector array will be completed this year and actual final assembly will have begun. The completion of this experiment should provide new U.S. capabilities in detection and characterization. Work continues on germanium detector arrays, the liquid and gas xenon gamma-ray spectrometers, hydrogen isotope resonance plastic scintillators for detection of thermal neutrons, coherent wave detection of neutrinos and for a new method for characterization of signatures in the atmosphere. Evaluation of three different experimental approaches to neutrino detection also continues.

An operational prototype system for analyzing data from hydroacoustic, seismic, satellite and other sensors will be developed and delivered to AFTAC to test advanced data fusion concepts which might be used in their operational monitoring system.

Program Element # 62714E
USDR&E Mission Area: 530 (TIARA)

Title: Nuclear Monitoring
Budget Activity: 1. Technology Base

The demonstration system will provide AFTAC with automated techniques, involving expert systems, to analyze multisensor data and will also provide a historical template of past explosions as a basis for estimating locations and yields of future explosions.

c. FY 1988 Planned Program and Basis for FY 1988 Request: Final transfer and testing of the new Yield Estimation Techniques will be achieved. Installation will begin of a magnitude estimation system, based on DARPA research, by the Air Force which will give yield estimates directly from recorded waveforms. Discrimination will be enhanced by installation of an interactive graphics system which will implement short-period focal plane and first motion analysis, as developed by DARPA researchers, which can be used as a discriminant at the lowest magnitudes. For the smallest, shallow, perhaps decoupled explosions only regional phases can be used as discriminants. Thus laboratory, theoretical, and empirical studies of regional discrimination will continue; as will studies on detection in the face of improved methods of decoupling. Practical demonstrations of high frequency propagation characteristics will be designed and tested using data from Scandinavian arrays. An intelligent system for automated processing of data from high frequency seismic arrays will be completed and installed at the DARPA Center for Seismic Studies. The system will optimize processing of data from multiple seismic arrays and should demonstrate significantly improved capabilities to detect small regional events. Intensive analysis of this data should provide important discoveries in yield estimation, detection of very small events, and regional seismic propagation especially at high frequencies where decoupling is inefficient. DARPA will continue to support additional treaty-related technical studies as required by bilateral and international negotiations.

(TIARA) Development of nuclear materials detection technology with emphasis on extreme sensitivity and new radiation imaging techniques will continue to move us toward our goal of developing and demonstrating the technologies to detect, identify, and characterize nuclear materials and weapons in space by 1990.

In addition, these fundamental technologies will directly contribute to national capabilities in follow-on programs. These research and development investigations and technical demonstrations in space will lead to advances in monitoring equipment which relies on radiation detection technology, gamma-ray detection and imaging, neutron detection and imaging, low-energy neutrino detection, and trace isotope detection using resonance ionization spectroscopy (TIARA).

d. FY 1989 Planned Program and Basis for FY 1989 Request: Testing of a prototype system for intelligent processing of high frequency seismic array data will be conducted. Its purpose is to evaluate the applicability

of knowledge based technologies for use in processing data from a network of arrays that might be deployed to monitor the Soviet Union.

New methods for estimating yields of Soviet explosions will be tested and applied in operational use for their applicability to lower thresholds of yield estimation.

A large scale international experiment will be conducted under the auspices of the Conference on Disarmament Group of Scientific Experts. The test will involve the global operation of seismic stations, national and international datacenters, including one in the U.S., as well as high speed communications networks for the daily exchange and processing of seismic data from the global system.

The space-borne neutron and gamma detector arrays will be delivered for integration on the Titan spacecraft for launch by a Titan missile.

Technical support to ongoing bilateral and international negotiations will continue.

e. Program to Completion: The research program has provided several options for improving the verification of the Threshold Test Ban Treaty and a possible lower yield treaty. The seismic research requirements in future years will be driven by negotiation opportunities as they appear. We anticipate that these programs in low level yield estimation, and in regional discrimination will be conducted at a level to support policy initiatives in this area. Because of the element of possible evasion by foreign nations, the program is a continuing one since discrimination of natural seismic events from weak signals and/or decoupled explosions as seen at regional distances will require theoretical, experimental, and systems capabilities not yet established.

Continued development of nuclear materials detection technology with emphasis on extreme sensitivity and new imaging techniques will move us toward our goal of developing and demonstrating the technologies.

f. Milestones:

Late FY 1986	Mid FY 1987	Statistical magnitude: advanced yield determination system completed and transferred to the Air Force.

FY 1988-1989 RDT&E Descriptive Summary

Program Element # 62714E
USDR&E Mission Area: 530 (TIARA)

Title: Nuclear Monitoring
Budget Activity: 1. Technology Base

Last Year's Reported Plan	Current Plan	Milestones
Late FY 1986	Completed	Development of improved magnitude yield and discrimination regional parameters from theoretical calculations.
Early FY 1987	Early FY 1987	Evaluation of advanced seismic array technology in Norway.
- -	Late FY 1987	Testing of Prototype of a Gamma Ray Detector.
Early FY 1988	Early FY 1988	Demonstration and Evaluation of high frequency analysis processing system.
- -	Late FY 1989	Delivering of Space borne neutron and gamma detector arrays for integration to spacecraft.
- -	Early FY 1990	Conduct of International Data Exchange Experiment under auspices of conference on Disarmament, Group of Scientific Experts.

g. Explanation of Milestone Changes: The delay in completing the evaluation report to the Conference on Disarmament is due to the decision by that multilateral group to have a more detailed report than was originally planned. The delay in completing the Space Shuttle experiments is due to the Space Shuttle accident.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63226E
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

A. RESOURCES (PROJECT LISTING): ($ in Thousands)

Project Number	Title	FY 1986 Actual	FY 1987 Estimate	FY 1988 Estimate	FY 1989 Estimate	Additional to Completion	Total Estimated Costs
TOTAL FOR PROGRAM ELEMENT		192,124	159,771	245,624	272,246	Continuing	TBD
EE-2	TEAL RUBY Experiment	21,245	7,900	6,000	15,700	48,300	297,474
EE-3	X-Wing/RSRA	13,800	28,000	15,000	10,000	115,000	211,361
EE-9	X-29 Advanced Technology Demonstrator	7,400	1,000	1,000	2,000	0	133,504
EE-16	Long Range Interceptor Experiment	2,628	20,000	18,000	20,500	71,000	132,128
EE-17	Detection of Aircraft (HI-CAMP)	2,996	3,000	3,000	3,000	6,000	16,006
EE-18	Advanced Undersea Vehicle	11,300	13,875	22,500	20,000	50,000	117,675
EE-19	Advanced Cruise Missile Technology	3,964	4,000	6,000	6,000	18,000	36,964
EE-21	Armor/Anti-Armor	0	2,300	16,570	34,060	137,000	187,630
EE-23	Enhanced Fighter Maneuverability	0	0	15,000	10,000	20,000	45,000
EE-24	Advanced Short Takeoff/ Vertical Landing	0	0	5,000	10,000	20,000	35,000

* Total includes classified projects not identified herein.

Program Element: #63226E
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED:

TEAL RUBY Experiment: (TIARA) This is a space experiment to demonstrate infrared detection of strategic aircraft from a space platform, measure target and clutter background signatures from space, and demonstrate advanced infrared mosaic detector technology. These technologies, as well as the infrared phenomenology data on targets and backgrounds, will be key to meeting the future national security requirements of the Air Defense Initiative, and the Services.

X-Wing/RSRA: This program is a major innovation in vertical takeoff and landing aircraft design which, by stopping the rotor in flight, combines the vertical lift efficiency of a helicopter with the speed, range, and altitude performance of a fixed wing aircraft. Design analysis indicates an operational X-Wing vehicle would have approximately three times the speed, range, and altitude performance of a conventional helicopter with equivalent payload lifting capability. These characteristics enable a very broad operational applicability such as: more flexible sea-basing for the Navy in conducting long range anti-submarine warfare; over-the-horizon targeting of missiles, and early warning for advanced fleet air defense concepts.

X-29 Advanced Technology Demonstrator: The X-29 Advanced Technology Demonstrator program is designed to develop and demonstrate advanced aerodynamics, structures and flight control technologies. This aircraft, made possible with advanced composite structure and a digital fly-by-wire flight control system, is being flight tested to investigate and quantify the technical benefits and performance capabilities of such an integrated advanced technology vehicle. Flight test results have developed confidence in numerous individual technologies, making them available as viable design options for advanced tactical aircraft and greatly reducing the risk, time and cost associated with future applications. Testing at high angle of attack will assess capability and performance in an expanded flight envelope.

Long Range Interceptor Experiment: The focus of this program is on the development of technology for a non-nuclear anti-air weapon. The weapon has potential for a dramatic advancement in anti-air warfare and features: (1) very short travel time for rapid force projection; (2) very large attack footprint which limits defense avoidance (or electronic countermeasures); (3) high mobility and flexible basing (air, ship, or ground launch options); (4) difficult detection by the enemy that attack is under way; (5) high

potential for covert use, particularly against an unsophisticated opponent; (6) large radar homing sensor and large kinematic footprint; (7) multiple operating modes (home-on-jam, anti-radiation-homing, active search); and (8) mission flexible and adaptable as a fast reaction "gap filler" as new threats emerge or as unforeseen crisis situations arise.

Detection of Aircraft (HI-CAMP): (TIARA) This project is an airborne Infrared (IR) sensor program to determine the IR signatures of: (1) strategic aircraft; (2) ground and sea targets; and (3) the natural and perturbed backgrounds against which these targets are observed from a spaceborne or high altitude airborne IR surveillance sensor. This project will provide the data base for the design of advanced space surveillance systems and will guide the development of the technology base. The HI-CAMP (Highly Calibrated Airborne Measurements Program) II effort was initiated in FY 1981 to provide the above IR signatures through airborne measurements aboard a U-2 aircraft and to support the mission planning and flight operations of the TEAL RUBY Experiment (Project EE-02). The HI-CAMP II sensor was developed to include: (1) a stabilized sensor platform (improved by a factor of ten); (2) a new element, hybrid silicon detector/multiplexor chips (one for short and one for long wavelength); (4) the focal plane drive electronics; (5) modified platform; and (6) a new correlation tracker subsystem for tracking lower contrast targets. The improved gimbal system permits long atmospheric slant path observations. The HI-CAMP hardware/software technologies and the target/background phenomenology data bases are key to the development of future systems to meet requirements of the Air Defense Initiative, and the Services.

Advanced Undersea Vehicle (TIARA): The objective of this project is to develop and demonstrate advances in technology required for autonomous undersea vehicles.

Advanced Cruise Missile Technology: Improving Warsaw Pact cruise missile defenses require that future generations of these weapons possess substantially improved penetration capability and lethality; this is a long term objective for DARPA and DoD. During FY 1985, increased DoD attention began in two additional areas of applications: (1) precision, non-nuclear attack and (2) location and identification of mobile targets. The Advanced Cruise Missile Technology program is a subcomponent of this overall thrust, developing major advances in propulsion technology for next generation systems applicable to this class of problems. Propulsion concepts which may greatly improve survivability, lethality and range-payload

initiated in the areas of V/STOL flight controls, integrated aerodynamics and propulsion, aerocoustic fatigue of aircraft structures, wind tunnel models, etc. This new start follows through on those preliminary efforts and will define the technology base for the possible fabrication of a feasibility demonstration.

C. COMPARISON WITH FY 1987 DESCRIPTIVE SUMMARY:

The decrease in the FY 1987 estimate is largely the result of the restructuring of the Advanced Cruise Missile Technology program and the Congressionally directed reductions in the Advanced Undersea Vehicle and the Detection of Aircraft (HI-CAMP) programs. These reductions were partially offset by a cost growth in the X-Wing/RSRA program, which was caused by problems in the manufacturing of the rotor blades and in the fabrication and testing of the flight control system, and by a Congressionally directed continuation of a classified program. The increase in the FY 1988 estimate is caused by the initiation of the Enhanced Fighter Maneuverability and the Advanced Short Takeoff/Vertical Landing programs and by increases in classified programs. The FY 1988 increase was kept to a minimum by reductions in the Long Range Interceptor Experiment and the Advanced Cruise Missile Technology programs, by the cancellation of the planned start of the Naval Battle Management program, and by reducing the funding for the initiation of the Armor/Anti-Armor program.

D. OTHER APPROPRIATION FUNDS: Not Applicable.

E. RELATED ACTIVITIES:

TEAL RUBY Experiment: (TIARA) The TEAL RUBY experiment provides the transition of DARPA concept, technology and design data into a variety of future space systems being considered by the Air Force, Navy and Army. TEAL RUBY will provide global background data, target signature data (for band selection) and validation of the mosaic concept for the Air Force Advanced Warning System, the Navy Integrated Tactical Surveillance System (ITSS), Air Force Space Based Surveillance Systems (SBSS) and, the Space Based Laser programs. The TEAL RUBY international cooperation effort which includes joint experiments with Canada, Australia and the United Kingdom, has been formulated and chartered under the Technical Cooperation Program (TCP) (Subgroup J-Infrared) in order to facilitate the joint experiments and to exchange data in cooperative defense areas.

product are being examined. Vehicle concept options include high/fast (100,000 feet/Mach 3.5), low/slow (sea level/subsonic) as well as other variants (such as high-fast transit and low/fast penetration). Advanced propulsion will enable the design of either air launched, long standoff range, air to ground theater nuclear missiles or large payload, precision accuracy, conventional munitions for use in theater or strategic roles.

Armor/Anti-Armor Technology: (NEW START) This project is dedicated to advanced development of successful concepts developed under PE 62702E, TT-04, Advanced Armor Technology which will culminate in a proof-of-principle demonstration which will be evaluated with respect to military requirements and cost to determine whether advanced development is appropriate. Examples of developments anticipated in this program include: advanced chemical energy warheads; improved kinetic energy projectiles; light and heavy armors with significantly increased effectiveness and reduced weight and cost; active protection systems providing currently unachievable levels of protection; advanced combat vehicle testbeds providing greatly improved survivability, effectiveness, and tactical and strategic mobility; and systems providing high effectiveness against tanks and helicopters with order-of-magnitude logistic reductions.

Enhanced Fighter Maneuverability (EFM): (NEW START) The EFM program will provide dramatic exchange ratio improvements through increased maneuverability for fighter aircraft during close-in aerial combat, as well as transonic and supersonic engagements and ground attack. Several enabling technologies will be integrated to expand the maneuvering flight limits of fighter aircraft, including vectored thrust, integrated control systems, and aircrew assistance. Improved aircraft performance and stability will provide high angle of attack control for rapid fuselage pointing and shooting, and improved aircrew protection for dealing with high linear and angular accelerations.

Advanced Short Takeoff/Vertical Landing (ASTOVL): (NEW START) The majority of tactical, fixed-wing aircraft in the United States inventory are constrained to airbases with long runways which are vulnerable to specific threat systems (ground-to-ground missiles, chemical munitions, etc.) The British and United States Marine Corps pioneered the use of subsonic V/STOL attack aircraft (the AV-8B HARRIER) to enhance tactical flexibility. This ASTOVL program is an outgrowth of the US/UK MOU to jointly develop a broad research base leading to the feasibility demonstration of a high performance, supersonic aircraft with vertical lift capabilities. In an earlier effort supported by Nunn-Quayle funding, several projects were

Program Element: #63226E
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

X-Wing/RSRA: This is a joint activity with NASA. Related Technical IR&D work is conducted by the David Taylor Naval Ship Research and Development Center.

X-29 Advanced Technology Demonstrator: A DARPA/Air Force Memorandum of Agreement was signed for the Air Force Systems Command to act as the DARPA Agent responsible for procurement and technical monitoring of the design and fabrication effort. The Air Force Program Office will also address the military utility of the numerous X-29 advanced technologies and their importance to the Services, advanced flight vehicle programs and especially the Advanced Tactical Fighter. The X-29 program exploits and extends research in the use of advanced composite materials, computer aided design, advanced aerodynamic and structural analytical design methods, and digital flight control design techniques previously conducted by the Air Force, Navy, NASA and industry. A DARPA/NASA Memorandum of Agreement was signed for NASA Ames, Dryden Flight Research Facility to conduct the flight test phase of the X-29 program. Also, NASA Langley has conducted structural dynamic testing and high angle of attack and spin wind tunnel testing to determine the aerodynamic coefficients and stability derivatives to use in Air Force, NASA and contractor ground simulations of the planned flight vehicles. In order to more rapidly transition the X-29 technologies, DARPA has formed the X-29 Future Applications Committee composed of potential corporate and government users to receive real-time results from the program so that results and lessons learned can be factored into other programs.

Long Range Interceptor Experiment: This work is related to programs of the Air Force Ballistic Missile Office, the Naval Surface Weapons Center and the Naval Air Systems Command.

Detection of Aircraft (HI-CAMP): (TIARA) HI-CAMP is related to other DARPA projects as follows: (1) TEAL RUBY, (Project EE-02, PE 63226E): HI-CAMP is the source of target and background data for TEAL RUBY experiment planning, and will collect simultaneous background and target truth data during TEAL RUBY experiments for calibration; (2) Strategic Aircraft and Cruise Missile Defense (SACM) (Project ST-13, PE 62301E): HI-CAMP is the only source for aircraft infrared (IR) signatures needed for the IR-radar fusion task in this project; (3) ADI (Air Defense Initiative) (PE 63424F): HI-CAMP is the only source of target IR signature data for ADI until the TEAL RUBY launch; (4) The Technical Cooperation Program (TTCP) with United Kingdom, Canada, and Australia. These nations require and are using HI-CAMP data to determine the vulnerabilities of their own systems, to infrared detection; (5) classified programs: all efforts within this project have been coordinated with related classified activities.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63226E
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

Advanced Cruise Missile: The Advanced Cruise Missile Program is directly related to programs managed by the Joint Cruise Missile project office and the Air Force Aeronautical Systems Division, Deputy for Systems and Deputy for Development planning. The engine developments are related to small engine research at the Air Force Aeropropulsion Laboratory, the Army Tank and Automotive Command and the Naval Air Propulsion Center.

Armor/Anti-Armor Technology - Armor/Anti-Armor Technology overall coordination of efforts is maintained with representatives of the Office of the Director of Defense for Research and Engineering, the offices of the Service Assistant Secretaries responsible for research and advanced development, and the corresponding Service headquarters staff offices. This program is overseen directly by an Executive Steering Committee consisting of representatives from the Army, Marine Corps, and DARPA. In addition, direct coordination with appropriate Service laboratories is maintained through meetings and conferences. These include the Army Ballistic Research Laboratory, Tank Automotive Command, Armament Research and Development Command, Missile Command, Laboratory Command, and others as appropriate.

Enhanced Fighter Maneuverability (EFM) - A Memorandum of Agreement between DARPA and the Navy was signed for the Naval Air Systems Command to act as the DARPA agent responsible for procurement and technical monitoring of the design, fabrication, and test efforts. This is in concert with an EFM Memorandum of Agreement between DARPA and the German Federal Ministry of Defense. A Navy Program Office has been established at the Naval Air Test Center for the conduct of the EFM program. NASA Langley Research Center will provide wind tunnel testing of high angle of attack maneuvering for the EFM flight demonstrator. A Supermaneuverability Steering Group has been established between DARPA, NASA, the Navy and the Air Force to coordinate research and technology demonstrations in this area. Other flight demonstrators that will add to understanding of the EFM flight regime are NASA's F-18 High Angle of Attack Research Vehicle, the DARPA/NASA/Air Force X-29 Follow-On program, and the Air Force STOL/Maneuver program.

Advanced Short Takeoff/Vertical Landing (ASTOVL): With the assistance of the International Research Program Initiatives, DARPA augmented the US effort under the US/UK MOU for supersonic STOVL research dated 15 January 1986. In this process, DARPA formulated a multiyear technology development plan that would mature all the relevent technologies by the early 1990s. This mature technology base would enable a

national decision to be made on a supersonic STOVL research aircraft. The DARPA program plan has been instrumental in focusing the ongoing research efforts in both NASA and USAF by directing them towards a common objective, a research aircraft in the early 1990s. While the funding (Service and NASA) and management remain the responsibility of the agency involved, the time phasing and work emphasis are aligned to support the DARPA program plan. The DARPA initiative supported a significant advancement under the US/UK MOU by funding an integrated research effort between the NASA facility and the Royal Aircraft Establishment (RAE). NASA is providing flight control research on an AV-8B while RAE is providing complementary research on an RAF TAV-8A.

F. WORK PERFORMED BY:

TEAL RUBY Experiment: (TIARA) The TEAL RUBY effort is performed by industry (76%), government in-house laboratories (15%), and by a Federal Contract Research Center (FCRC) (9%). Rockwell International, Seal Beach, California, is the prime contractor on the TEAL RUBY sensor; support contractors are: Logicon, San Pedro, California; Magnavox, Torrance, California; MRJ, Fairfax, Virginia; Riverside Research Institute, Arlington, Virginia; the Environmental Research Institute of Michigan, Ann Arbor, Michigan and E-Systems, Arlington, Virginia. The FCRC support is provided by the Aerospace Corporation, El Segundo, California. The program is managed by the Air Force Space Division, Los Angeles, California, with support in Naval areas of interest by the Naval Ocean Systems Center, San Diego, California. Target support is provided by the Air Force Geophysics Laboratory (AFGL), Hanscom AFB, Massachusetts and operational support will be provided by the Air Force Satellite Control Facility at Sunnyvale, California.

X-Wing/RSRA: Sikorsky Aircraft performs 90 percent of the effort, NASA and the David Taylor Naval Research and Development Center perform 10 percent with in-house activities.

X-29 Advanced Technology Demonstrator: Prior to the delivery of the X-29 to the government approximately 90% of the effort was performed by industry. The principal contractor was Grumman Aircraft Corporation, Bethpage, New York. Approximately 10% was being performed in-house by the Air Force Systems Command and by numerous NASA centers. The NASA and Air Force percentage have increased to a much larger share as the flight test phase started. The technical agent responsible for program oversight is the Air Force Wright Aeronautical Laboratories, Flight Dynamics Laboratory, assisted by NASA Ames, Dryden Flight Research facility and the Air Force Flight Test Center, Edwards AFB, California.

Program Element: #63226E
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

Long Range Interceptor Missile: About 90% of the effort is conducted by industry. The major contractors are: Decision Science Applications, Arlington, Virginia; Hughes Aircraft Company, Fullerton and Canoga Park, California; Raytheon Company, Lexington, Massachusetts; Lockheed Missiles and Space Company, Palo Alto, California; and Space Applications, Incorporad La Jolla, California.

Detection of Aircraft (HI-CAMP): (TIARA) Approximately 95% of this work is performed by industry and 5% by government laboratories. Major industrial contractors are: Lockheed Missile and Space Company, Palo Alto, California; MRJ, Fairfax, Virginia; Photon Research, LaJolla, California; and ERIM, Ann Arbor, Michigan; Optimetrics, Ann Arbor, Michigan; Technology Research Associates, Camarillo, California and Space Instruments, San Diego, California. Government laboratories include: Air Force Geophysics Laboratory, Hanscom Air Force Base, Massachusetts; the Naval Ocean Systems Center, San Diego, California; and the National Aeronautics and Space Administration. Federal Contract Research Center support ir ludes that of the Aerospace Corporation, El Segundo, California and the Institute for Defense Analyses, Arlington, Virginia.

Advanced Undersea Vehicle: (TIARA) Approximately 90% of the effort is performed by industry and 10% by government laboratories. The major contractors are Scientific Research Laboratories, Santa Barbara, California and Rockwell International, Anaheim, California. The government laboratories which support this project are the David Taylor Naval Ship Research and Development Center, Carderock, Maryland, and the Naval Underwater Systems Center, Newport, Rhode Island.

Advanced Cruise Missile Technology: Industry provides 98% percent of the effort for this program and government laboratories the remaining 2%. LTV Aerospace, Dallas, Texas is the prime contractor with the engine design, analysis and test subcontracted to Garret, Phoenix, Arizona.

Armor/Anti-Armor: Approximately 80% of the effort will be performed by industry. The major contractors are: General Motors, Goleta, California; General Electric, Pittsfield, Massachusetts; Physics International, San Leandro, California; and Battelle Institute, Columbus, Ohio. The Los Alamos National Laboratory, New Mexico and the Lawrence Livermore National Laboratory, Livermore, California will perform 15% of the effort. The remaining 5% will be performed by the University of Texas, Austin, Texas.

Program Element: #63226E
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

Enhanced Fighter Maneuverability (EFM): Prior to delivery of the EFM flight demonstrator to the Government, approximately 90% of the effort will be performed by industry. The principle U.S. contractor is Rockwell International Corporation, Los Angeles, California, with General Electric Corporation, Daytona Beach, Florida and Lynn, Massachusetts as subcontractors. Work in Germany, conducted under German funding, is being performed by Messerschmitt-Bolkow-Blohm, Munich, Federal Republic of Germany. Approximately 10% of the development effort will be performed by the Naval Air Systems Command, principally the Naval Air Test Center, Patuxent River, Maryland; the Naval Air Development Center, Warminster, Pennsylvania; and NASA Langley Research Center, Hampton, Virginia.

Advanced Short Takeoff/Vertical Landing (ASTOVL): Approximately 50% of the effort is performed by industry and 50% is performed by government activities. The major contractors are General Electric, Evendate, Ohio; Pratt & Whitney, Palm Beach, Florida; McDonnell-Douglas, St. Louis, Missouri: Lockheed Aircraft Corporation, Marietta, Georgia. The in-house effort is being performed at NASA Ames Research Center, Sunnyvale California, NASA Lewis Research Center, Cleveland, Ohio and NASA Langley Research Center, Hampton, Virginia.

G. PROJECTS LESS THAN $7 MILLION IN FY 1988:

X-29A: The X-29A Advanced Technology Demonstrator is evaluating significant advancements in aerodynamics, structures, and flight control technologies. In FY 1986 flight testing expanded the entire altitude and speed flight envelope of the X-29A to elevated load factors. Research efforts focused on the advanced aerodynamic, structural, and flight control techniques. Performance, stability and control test data have been correlated and compared to analytical and wind tunnel predictions in order to validate the design process and create the database necessary to transition the X-29A results. Seventy-two flights were conducted by a combined NASA, Air Force Wright-Aeronautical Laboratories Air Force Flight Test Center, and Grumman Corp Test Team. In FY 1987, continued flight research on the first X-29A will determine additional performance data using a calibrated jet engine for exact thrust measurements. Military applications will be evaluated via handling qualities testing for air combat maneuvering and air-to-air tracking tests. The second X-29A aircraft will begin modification with a spin parachute and augmented flight control system and instrumentation for high angle of attack testing. In FY 1988 research flight

Program Element: #63226E
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

testing on the first X-29A aircraft will be completed with detailed structural loads flight date being compared to theoretical predictions at many points in the flight envelope. The second X-29A vehicle will be delivered to Edwards AFB to begin extensive ground testing of the flight control system and certification of the spin parachute. A major effort will be conducted to transfer flight test information to the user community from the research flights. Flight testing of aircraft number two will be conducted during FY 1989. A gradual build-up in angle of attack and angular rate will provide safety near the stall boundary of the flight envelope. Control system effectiveness in the rol and pitch axes will be evaluated at high angles of attack to validate the design goals of the forward swept wing. The extensive flight test instrumentation system of the X-29A will provide data that were previously unattainable. Flight testing for the X-29A follow-on program will be completed during FY 1989. The first quarter of FY 1990 will be devoted to data reduction and reporting of test results and comparisons with analytical predictions.

Detection of Aircraft (HI-CAMP): (TIARA) In early FY 1986 a very successful cooperative flight program was carried out with Canada over the Northwest Territories. In FY 1986 this program focused on preparations to support of the major DARPA/Air Force TEAL RUBY Satellite Experiment which was to have been launched on the Shuttle in early 1986. HI-CAMP has the same primary infrared spectral bands as the TEAL RUBY sensor but with higher resolution. HI-CAMP was planned to be used to collect simultaneous background and target truth data during many of the TEAL RUBY experiments beginning in July 1986 to help in experiment diagnostics and calibration purposes. Target missions would have included aircraft, tactical and ships, tactical Army targets and classified targets. However, due to the Shuttle accident, the TEAL RUBY launch was postponed to sometime after 1990, and HI-CAMP's focus was re-directed toward addressing problems of the Air Defense Initiative (including the Navy Outer Air Battle challenge) and other IR surveillance issues. With the postponement of TEAL RUBY, the importance of the HI-CAMP II Program to the many IR surveillance communities and the Services has increased greatly. In FY 1987 the emphasis of the HI-CAMP program will shift away from the planned participation in actual TEAL RUBY missions to addressing a number of very important IR surveillance phenomenology and technology issues. HI-CAMP will gather phenomenology data key to the development of real-time processing algorithms for detection, tracking and identification of a wide variety of targets, both tactical and strategic, over varying backgrounds and atmospheric conditions. Emphasis will also be placed in applying hardware and software technologies being developed in other DARPA programs (supercomputing, artificial intelligence, etc.) to the implementation of

these algorithms in developing real time capabilities that are required for space based and high altitude IR surveillance systems. Studies will be performed in FY 1987 that will address the need for a follow-on program to expand the current IR technology and phenomenology bases and potentially demonstrate these new capabilities as an integrated prototype operational system. Another major thrust of the program will be the development of advanced models based on the analysis and understanding of real IR data. Realistic, thoroughly verified IR models of targets, backgrounds and atmospheric transmission are key tools for the evaluation of surveillance hardware, software and architectural performance in real warfighting scenarios. Another role of the HI-CAMP program will be to support the collection of IR data for the Allied nations (United Kingdom, Canada, Australia) participating with the U.S. in The Technical Cooperation Program. Each of these nations is utilizing HI-CAMP data gathered against their own targets and backgrounds to establish future system requirements that meet their military needs. Data has already been collected in the UK and Canada, but a deployment to Australia is planned to address their specific needs and a general community need for tropical IR data. Since TEAL RUBY will now be launched from Cape Kennedy rather than Vandenberg, the orbit inclination will change. In order to gather the IR data over the real threat corriders, it is imperative to deploy HI-CAMP to gather this data. HI-CAMP gathered data will also play a major role in the replanning of many of the TEAL RUBY missions due to the shift in inclination and the IR lessons learned from HI-CAMP in the interim prior to the TEAL RUBY launch. HI-CAMP II or its follow-on system will still be required to provide real time support to TEAL RUBY on-orbit mission operation.

Advanced Cruise Missile Technology: During FY 1986 a significant milestone was reached. A fabrication technique was validated that resulted in a 15 inch turbine wheel being spun at room temperature at 40,000 Revolutions Per Minute (RPM). The ability of a turbine wheel to survive the loading and stress level will allow significant power extraction from advanced engines. The second milestone was the hot spin of a coated carbon-carbon sample at 3,100 Degrees Farenheit and 50,000 RPM for over five hours. The stress on the tip of this sample approached 250,000 G's and the sample kept its structural integrity and the oxidation protection coatings remained in place. During FY 1987 the two milestones of FY 1986 will be exploited in a synergistic approach. A large turbine rotor will be coated with the oxidation protection and hot spun at 3,100 Degrees Farenheit. This will demonstrate that high temperature carbon-carbon turbine machinery is really possible. The rotor size selected for the demonstration will be chosen to interface with the ongoing USAF Expendable Turbine Engine Component (ETEC) program. The AF is pursuing a more evolutionary development of all aspects of turbine engines for future cruise missile systems. The

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63226E
USDR&E Mission Area: 530

Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

DARPA program is emphasizing a high risk, revolutionary breakthrough in turbine and hot section design. During FY 1987, four ETEC prototype rotors along with a high temperature carbon/carbon DARPA sponsored rotor will be built and tested and a design for an ETEC engine modification to accept a DARPA rotor will be developed. During FY 1988, additional carbon-carbon engine components will be developed and tested for transition to one of the USAF ETEC prototype engines. After completion of the ETEC tests on other subsystem components, the engine prototype will be modified to accept and evaluate the significant potential increase in performance allowed by the DARPA advanced carbon-carbon component. This approach insures that the USAF maintains an evolving technical base and allows a potential breakthrough in engine performance with the user actively involved. A low level study effort will be maintained in parallel with the technology effort to evaluate mission applications as national policy evolves on strategic and theater weaponry. In FY 1989 and FY 1990, an engine prototype more fully optimized for the high temperature potential of carbon-carbon turbomachinery will be demonstrated and a system concept for its use will be proposed based on evolving strategy requirements.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-2
Program Element: #63226E
USDR&E Mission Area: 530 (TIARA)

Title: TEAL RUBY Experiment
Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: DARPA initiated the TEAL RUBY Program in 1974 to demonstrate the feasibility of detecting strategic air vehicles using a space-based infrared sensor and to provide a future option for warning of bomber attack against North America or Naval Battle Groups. Detection of weak aircraft signatures against the strong earth background clutter required a large number of advanced technologies, with the most critical being infrared detectors. Target and background measurements performed by DARPA showed the feasibility. These measurements, coupled with successful production of large mosaic arrays, formed the basis for TEAL RUBY. Each focal plane zone contains detectors. Spectral filters were developed to demonstrate spectral in a single focal plane. Although the filter was demonstrated successfully in the laboratory, it was not included in the TEAL RUBY flight sensor due to cost and schedule constraints. Measurements will be performed from orbit using cooperative air vehicle targets to validate performance. The sensor is designed with sufficient sensitivity to detect targets. These countries are major participants in the DARPA TEAL RUBY and HI-CAMP Air Vehicle Detection programs through The Technical Cooperation Program (TTCP) and have technical and military personnel as full time members in the TEAL RUBY Program Office. Infrared background measurements, required for the design of future operational sensors, will be made on a worldwide basis and under a variety of seasonal, climatological and geographic conditions. In addition, the feasibility of using the sensor has been evaluated and specific experiments are planned. Data will also be collected against ships, tactical missiles, armor and classified targets. On-orbit TEAL RUBY experiments will be performed to support the requirements of DARPA, Air Force, Navy, Army, and Air Defense Initiative.

2. Program Accomplishments and Future Program: In the design and development of the TEAL RUBY sensor, many technologies of great importance to future DoD systems have been significantly advanced. These advances include the development of lightweight optical elements; a lighweight space qualified cryostat; the development of a testing machine that tests at cryogenic operating temperature; the technology of invar mounting and the design, build, and test of electronics that operate in a cryogenic environment. All of these technologies as well as the infrared phenomenology data on targets and backgrounds will be key to meeting the future national security requirements of the Air Defense Initiative, and the Strategic.

3. FY 1986 Accomplishments: As the launch of TEAL RUBY approached, the program emphasis shifted to understanding how the sensor performs based on radiometric chamber testing; completing sensor/spacecraft integrated testing to meet the launch date and the development of the operational software and hardware to gather data on-orbit, process the data and interpret the results. These efforts were all completed satisfactorally. Hardware/software

Project: #EE-2
Program Element: #63226E
USDR&E Mission Area: 530 (TIARA)

Title: TEAL RUBY Experiment
Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

development and training for the operation of the TEAL RUBY Mission Operations Center (MOC) continued and rehearsals for launch and on-orbit operations with the Satellite Control Facility were begun. Software development to support the MOC and data analysis continued to receive strong emphasis due to its criticality and complexity. The data analysis software was based upon the experience and software generated by the DARPA Highly Calibrated Airborne Measurements Program (HI-CAMP) sensor and provided the basis for future systems analysis. All TEAL RUBY efforts were on schedule to support the July 1986 Shuttle launch. After the Shuttle Challenger failure, program emphasis shifted to addressing storage of the spacecraft sensor, maintaining key people and the best and fastest way to get TEAL RUBY in orbit. Based on the most recent NASA manifest, the new launch date will slip with the Air Force and DARPA applying pressure to increase the TEAL RUBY priority and move it up on the Shuttle manifest. Also, due to the decision to mothball Vandenburg AFB for Shuttle launches, TEAL RUBY will now launch from Cape Kennedy.

b. FY 1987 Program: FY 1987 funds will support the closeout of spacecraft/sensor system testing (these efforts were slowed after the accident to minimize cost); closeout and verification of ground based data processing system software, maintenance of a small mission operations staff to complete and document planned missions; the performance of storage studies; preparations for, and actual storage of the spacecraft/sensor at Rockwell, Seal Beach and the completion of modifications to the sensor earthshield. Some funds will also be expended to study possible upgrades to the TEAL RUBY system that could be made while waiting for launch and look at the possibility of reconfiguring TEAL RUBY to fly on an expendable launch vehicle (ELV).

c. FY 1988 Planned Program and Basis for FY 1988 Request: In FY 1988, replanning of modified and new TEAL RUBY on-orbit missions will begin based on new information learned from the DARPA Highly Calibrated Airborne Measurement Program (HI-CAMP) and other infrared sensor systems and on new requirements being established by the Air Defense Initiative, and the Services. Funds will also support the complete modification of uplink and downlink software required due to the Satellite Control facility's implementation of new software and computer systems under their Defense Systems Modernization program. Actual TEAL RUBY spacecraft/sensor hardware and software storage and maintenance will be funded for the full fiscal year.

d. FY 1989 Planned and Basis For FY 1989 Request: In FY 1989, efforts will begin to reconstitute the program in terms of spacecraft/sensor hardware/software systems, facilities like the Mission Operations Center, and most importantly the people who will carry the program through launch, on-orbit operations and data analysis. Planning for the retest of key spacecraft/sensor subsystems, facilities and software will begin. Mission planning for new and modified missions will continue. Storage/maintenance of the spacecraft/sensor and some facilities will be funded.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-2
Program Element: #63226E
USDR&E Mission Area: 530 (TIARA)

Title: TEAL RUBY Experiment
Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

e. Program to Completion: The program to completion will require reconstitution of all elements of the program to support launch, on-orbit operations, and data analysis. The spacecraft/sensor will be removed from storage, tested and prepared for the Shuttle launch. Similar activities will occur to bring facilities and software into final configuration. Rehearsals and operational demonstrations will be conducted in preparation for launch and on-orbit activities. Major efforts will be expended in planning for the wide variety of targets for dedicated TEAL RUBY experiments. After launch, TEAL RUBY will operate on-orbit. A complete analysis of the data will take about two years after the completion of on-orbit operations. When TEAL RUBY launches, it will still be the most capable infrared sensor system to address the many space-based air vehicle detection issues as well as issues associated with other targets (ships, missiles, armor, etc.) The on-orbit performance of TEAL RUBY technology and the infrared target and background phenomenology data collected are critical to the design, assembly, test and operation of future surveillance systems. Every effort should be made to fly TEAL RUBY as soon as possible.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestones
Late FY 1986		Shuttle launch of TEAL RUBY Spacecraft/sensor
Late FY 1987		Complete Orbital Operations.
Mid FY 1989		Complete Program.

g. Explanation of Milestone Changes: The Shuttle launch of TEAL RUBY, originally planned for July 1986 from Vandenburg AFB, has slipped due to the Shuttle Challenger accident. The current plan for a launch from Cape Kennedy is based on current NASA/DoD manifest discussions. Actions are being taken to try and move TEAL RUBY to an earlier launch date.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-FY 1989 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-03
Program Element: #63226E
USDR&E Mission Area: #530

Title: X-WING/RSRA
Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

H. PROJECTS OVER $7 MILLION IN FY 1988 - FY 1989:

1. Program Description: The X-Wing/Rotor Systems Research Aircraft (X-Wing/RSRA) will demonstrate a fundamental advanced in United States aeronautical technology. It will explore the feasibility of combining, in a single airframe, the best aspects of a helicopter and fixed-wing aircraft. Current helicopters have maximum forward speeds of approximately 225 knots and a very low dynamic performance, i.e., turn-rate, roll-rate, rate-of-climb, etc. Current fixed-wing aircraft have high forwards speeds and dynamic performance but poor low speed handling characteristics. Efforts to use aircraft in vertical modes, like the AV-8B V/STOL HARRIER, are limited to short transition times between horizontal and vertical flight. While not designed to hover, the AV-8B can hover at great expense in fuel usage and engine life. Successful demonstration of the X-Wing/RSRA will open a whole new field of aircraft design and mission application. Since the X-Wing rotor blades rotate in the helicopter mode and then lock into place for the fixed-wing mode, they are very stiff structural members. This stiffness leads to a higher dynamic performance in the helicopter mode as well as in the fixed-wing mode. The Army/NASA RSRA was modified to the accepted DARPA X-Wing rotor system for flight tests. In parallel with ground based propulsion testing, wing tunnel testing, and manned simulator training, the RSRA is being prepared for flight tests of gradually increasing complexity. The 50 hour flight test program will validate the X-Wing concept and provide valuable test data for the design of a military prototype.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: The most significant accomplishment during FY 1986 was the roll-out of the Rotor Systems Research Aircraft (RSRA). The aircraft was extensively modified to serve as the flying testbed for the X-Wing rotor system. The RSRA was shipped to the Dryden Flight Test Center for final assembly and checkout. The Powered System Test Bed (PSTB) became operational and has served to identify and allow safe correction of start-up problems associated with the power train. The PSTB has been invaluable in the debugging of control software and propulsion hardware. It has uncovered and resolved problems before they reach the flight test aircraft, thereby supporting both the fast paced integration schedule and the rigorous safety of flight requirements for this revolutionary aircraft. The NASA Flight Readiness Review Board has approved the manned simulation as adequate for the first phase of flight testing to begin during FY 1987.

b. FY 1987 Program: In order to lead quickly to a flight test demonstration of the X-Wing concept, several related projects are maturing simultaneously and are providing interactive data on a daily basis. Powered wind tunnel model: this scale model was used to explore the aeroelastic properties of the X-Wing blades and the handling characteristics of the various vehicle configurations. During FY 1987, the data from the wind tunnel testing will be used to make the system simulations more realistic in the manned vehicle motion simulator; to make the hardware testing more rigorous in the vehicle management system laboratory; and to define flight test procedures that gain the required system

Project: #EE-03
Program Element: #63226E
USDR&E Mission Area: #530

Title: X-WING/RSRA
Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

data and yet maintains an adequate margin of safety. Powered System Test Bed (PSTB): the PSTB will continue to test all the full scale propulsion components under software control with a complete set of computers and software identical to that on the flight test aircraft. The plan is to run a 50 hour qualification test of the complete system prior to the first flight of the RSRA aircraft. PSTB endurance testing will always remain at least a factor of fifty hours ahead of the aircraft testing in order to watch for component degradation that might impact the flight test aircraft. Vehicle Motion Simulation (VMS): the VMS at NASA/AMES will continue through a manned simulation, to evaluate the response of the RSRA/X-Wing aircraft to various flight test condition and simulated emergencies. This current simulation will continually receive the latest data on predicted aircraft response as a training aid for the flight test pilots. Vehicle Management System: the Vehicle Management Systems Laboratory will continue to simulate vehicle control techniques with the actual hardware in the loop. The simulation will be run to determine the detectability of component failures, impacts on system stability under various flight conditions, checkout of the computer software routines as they become available, and numerous other validation and verifications tasks that support the flight testing. Flight Test Aircraft: the RSRA/X-Wing will be the flying laboratory test bed to evaluate the X-Wing concept. It will allow the gradual build up of all the various components in a carefully phased approach to insure system safety, weight and balance, control and stability, structural integrity, and numerous other design parameters.

c. FY 1988 Planned Program and Basis for FY 1988 Request: The final proof-of-concept for the X-Wing will be the conversion from rotary flight to stopped rotor (fixed wing flight) and back to rotary flight. This demonstration will take place in early FY 1988. At that time all advanced control modes will be fully demonstrated, such as higher harmonic control of the interaction between the rotor blades and the vehicle body. The validated design data from this test will be combined with the mission area analysis for an X-Wing vehicle. The combination of valid test data and mission requirements will allow the rationalization of a prototype demonstration vehicle. Emerging technologies and advanced design techniques will be used to propose a service related prototype with greatly improved range, payload, and mission performance characteristics. FY 1988 funding will be used to develop a preliminary design of a prototype that will be of high interest to the services and potentially our allies in NATO.

d. FY 1989 Planned Program and Basis for FY 1989 Request: FY 1989 funding will be used to develop a more detailed design as well as test advanced components that were identified as needing availability to support a prototype effort.

e. Program to Completion: The demonstration of conversion between rotary and fixed-wing flight program in FY 1988. A follow-on compilation of the data into the design of a military prototype in FY 1989 will complete the X-Wing/RSRA program.

FY 1988-FY 1989 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-03
Program Element: #63226E
USDR&E Mission Area: #530

Title: X-WING/RSRA
Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestone
Mid FY 1986	Late FY 1986	RSRA Roll Out
Late FY 1986	Mid FY 1987	First Flight Fixed Rotor
Mid FY 1987	Late FY 1987	Transition Rotary to Fixed-Wing

g. Explanation of Milestone Changes: The fabrication of the X-Wing blades is the largest structural composite ever fabricated. Problems in blade manufacturing to the stress levels required for flight safety delayed the availability of blades for flight test. Software development for the quadruply redundant flight control took longer than anticipated. A gear box failure in the ground-based propulsion test ring delayed final aircraft assembly. Since flight safety of this one-of-a-kind aircraft is of paramount importance, the assembly and test milestones were slipped until component confidence was firmly established.

I. TEST AND EVALUATION DATA: Not Applicable

J. COOPERATIVE AGREEMENTS: Not Applicable

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-16
Program Element: #63226E
USDR&E Mission Area: 530

Title: Long Range Interceptor Experiment
Title: Experiment Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Descriptive: The Long Range Interceptor Experiment (LORAINE) transitioned from the Strategic Technology program element 62301E, Project ST-4, in FY 1986. Focus of the LORAINE program has been on development of technology for a non-nuclear very long range anti-aircraft weapon launched from ship, land, or air. Candidates for the vehicle include maneuverable reentry vehicles and supersonic ramjets. The development is intended primarily for Naval battle group and Continental United States (CONUS) air defense applications. The weapon could be a fire-and-forget system with a goal for terminal footprints in excess of 100 nmi. By virtue of its speed the LORAINE could attack in very short timelines. By having a large search area the LORAINE minimizes the need for accurate pretargeting information, and coupled with its speed of reaction eliminates the need for update information in most scenarios. It is ideally suited to complement long range surveillance systems such as Over-the-Horizon (OTH) Radar and Space Infrared (IR) systems. These latter systems can be used to cue the LORAINE. LORAINE can also be used to provide the outer air defense for Naval battle groups.

2. Program Accomplishments and Future Programs: Efforts have been underway to resolve the demanding technical issues. A nearly full scale LORAINE concept demonstration will be developed. The program will include the development of the attendant cooling system; an appropriate prime power source; and all hardware miniaturization necessary to incorporate the LORAINE system into a package compatible with a variety of host platforms. The detailed LORAINE program plan is being developed. However, it is currently anticipated that a demonstration would be accomplished in the time frame.

a. FY 1986 Accomplishments: In FY 1986, initial development towards the demonstration of the Long Range Interceptor Experiment (LORAINE) was initiated. The principal objective of this phase, which extents to FY 1989, is to develop sufficiently robust algorithms to provide a high level of background clutter cancellation. To meet this objective for realistic stressing environments, captive flight tests are planned. Data will be collected over diverse terrains and used to fully develop and demonstrate the clutter suppression which will be required for an on-board real time operational mode. The associated electronics will incorporate advanced technology.

b. FY 1987 Program: IN FY 1987, the preliminary system design for the clutter test flights will be completed. Mission and simulation requirements will be addressed. Full up development of clutter cancellation algorithms and coding will be initiated. System studies will be initiated to evaluate potential vehicle applications. Additional sensor modes will be evaluated. Adjunct sensors will be considered.

c. FY 1988 Planned Program and Basis for FY 1988 Request: In FY 1988, system design for the clutter test flights will be completed. System integration of all sensor components will begin in preparation for captive flights tests.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-16
Program Element: #63226E
USDR&E Mission Area: 530

Title: Long Range Interceptor Experiment
Title: Experiment Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

d. FY 1989 Planned Program and Basis for FY 1989 Request: Captive flight clutter tests will be conducted by mounting the sensor assembly on a suitable delivery vehicle aerodynamic shell. Data will be analyzed to determine the required carrier vehicle performance. In addition, a suitable platform will have been identified for the sensor by the services, and planning and design for a full up series of free flight tests and intercepts will be initiated.

e. Program to Completion: This is a continuing program. The evaluation of sensor/ navigation techniques will be continued with LORAINE sensor captive flight test demonstration planned for late FY 1989, and full scale flight tests when a suitable flight vehicle is identified.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestones
Mid FY 1986	Late FY 1987	Complete LORAINE flight test planning
Late FY 1987	Late FY 1988	LORAINE clutter collection system integration begins
Late FY 1988	Late FY 1989	Captive flight clutter tests

g. Explanation of Milestone Changes: Initial milestones reported last year proved too aggressive. Schedule slippage has occurred due to reevaluation of possible carrier vehicles for the LORAINE sensor.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-18
Program Element: #63226E
USDR&E Mission Area: 530 (TIARA)

Title: Advanced Undersea Vehicle
Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

H. PROJECT OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The objective of this program is to develop and demonstrate advances in technology required for autonomous undersea vehicles. Technology areas to be investigated include: Autonomous navigation systems, high energy density power sources, advanced propulsion systems, low drag vehicle designs, advanced autonomous sensors, covert acoustic communications and autonomous control logic. Previous efforts (thru FY 1985) were reported in Program Element 6270E and summary details are contained in Project TT-3.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: In FY 1986, preliminary tests of low drag vehicle design were completed indicating the potential for a reduction in drag over conventional designs. Drag reduction was demonstrated. A program to demonstrate cooperative autonomous behavior was begun.

b. FY 1987 Program: Demonstration of the low drag vehicle design at higher speeds and in salt water is being conducted in the Langley Tow Basin during FY 1987. The fabrication of a Terrain and Obstacle Avoidance Sonar (TOAS) system was completed in early FY 1987. Autonomous logic for the TOAS will be completed in late FY 1987. Mission studies are continuing which will identify and demonstrate alternate uses for autonomous vehicles. Laboratory demonstrations of the intelligent control of Multiple AUV's are being completed in late FY 1987. Cooperative AUV activity will be demonstrated using two vehicles with acoustic and lidar sensors. This activity includes search, hazard avoidance and coordinated attack. Major contractors are Rockwell International, National Bureau of Standards, Decision Sciences, Inc. and the University of New Hampshire.

c. FY 1988 Planned Program and Basis for FY 1988 Request: A decision to continue to larger scale design and demonstration will be made at the time. Field demonstrations of multiple AUV control will begin in FY 1988. Autonomous TOAS system performance will be demonstrated in FY 1988 on board a testbed vehicle in a realistic environment. Demonstrations of the small scale covert acoustic communications system will be completed in late FY 1988.

d. FY 1989 Planned Program and Basis for FY 1989 Request: Further activities during FY 1989 will concentrate on the development of advanced autonomous sensors, (e.g., a second generation TOAS, an Acoustic Intercept Receiver) and advanced energy/propulsion systems, (e.g., an advanced Stored Chemical Energy Propulsion System, a diesel SCEPS, a secondary Lithium battery, or an artificial gill). Mission details as well as some Advanced Undersea Vehicle technology items can only be addressed at a higher classification level.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-18
Program Element: #63226E
USDR&E Mission Area: 530 (TIARA)

Title: Advanced Undersea Vehicle
Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

e. Program in Completion: This is a continuing program.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestones
Late FY 1986	Early FY 1986	Begin advanced technology demonstrations
Late FY 1987	Late FY 1987	Complete critical on-going technology demonstrations in hydrodynamics and communications
Late FY 1988	Late FY 1988	Demonstrate adaptive autonomous vehicle technologies

g. Explanation of Milestone Changes: Not applicable.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-21
Program Element: #63226E
USDR&E Mission Area: 530

Title: Armor/Anti-Armor Advanced Development
Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The objective of this project is to pursue advanced development (i.e. prototyping) of armor and anti-armor systems and subsystems. This is the next step after a proof-of-principle technology demonstration has been successfully conducted. Occasionally this phase may be entered into without such a demonstration. Typically, the goal of this phase is to develop a prototype or testbed system for a specific application. A number of additional constraints must be considered during this phase including weight and volume, ruggedness, environmental effects, operational considerations, and cost.

This project exists in conjunction with a related project in program element 62702E: TT-04, Armored Warfare Technology. In TT-04, improved armors, munitions, and systems are being developed in a competitive process culminated by a shoot-off and an evaluation based on the shoot-off results. Given successful results, each evaluation cycle is intended to result in at least one project transitioning to advanced development, i.e. to this program. Other programs may also enter this program without a shoot-off if the technologies are judged to be sufficiently mature.

2. Program Accomplishments and Future Programs: This is a new project starting in FY 1987, thus there are no current accomplishments.

a. FY 1986 Accomplishments: Not applicable.

b. FY 1987 Program: Two systems are expected to enter advanced development during FY 1987.

The proof-of-principle demonstration for a command and control system will take place under Project TT-04. If successful, advanced development will be pursued immediately.

The specialized light armor system is being developed in response to Marine Corps requirements. Contractor in-house shoot-offs will be evaluated for their application to a vehicle. This evaluation will be performed during late FY 1987, and advanced development will proceed immediately. This system will allow variable levels of protection to be applied depending on mission constraints and anticipated threats.

c. FY 1988 Planned Program and Basis for FY 1988 Request: Two systems are expected to enter advanced development during FY 1988. All these systems will have been through a proof-of-principle demonstration. It is also possible that some components or subsystems of the advanced combat vehicle will be suitable for this program during FY 1988, however, selections have not yet been made.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #88-21
Program Element: #63226E
USDR&E Mission Area: 530

Title: Armor/Anti-Armor Advanced Development
Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology

It is intended to fund the most successful chemical energy warhead competitor(s) to develop warheads for one or more specific applications. The selection of the application will be made depending on then-current Army and Marine Corps requirements and timetables. Likely candidates include Advanced Anti-Armor Weapon System-Medium (AAWS-M), Tube-launched, Optically-tracked, Wire-guided (TOW), and/or Dragon missiles.

It is intended to transition multiple competing vehicle survivability system contractors pending successful proof-of-principle demonstrations. A specific vehicle will be chosen for system integration.

d. FY 1989 Planned Program and Basis for FY 1989 Request: The FY 1989 program will continue development of projects initiated in FY 1988. In addition, several new systems will be added.

Armor systems developed for specific applications will provide significant survivability enhancement for the vehicles specified relative to the current and projected armors. Final selection of the appropriate vehicles will be made in conjunction with then-current Service requirements and timetables.

Promising kinetic energy penetrator candidates may enter advanced development during this period.

Advanced combat vehicle components anticipated to enter advanced development during this period include the elevated sensor, articulation and data links, basic vehicle frame, and the teleoperation/autopilot system. These will lead to a complete testbed integration in the FY 1990-1991 timeframe to demonstrate a combat vehicle system with significantly improved survivability, effectiveness, mobility, and strategic deployability on a schedule compatible with Army plans.

e. Program to Completion: This program will continue to transition successful efforts from TT-04, into advanced development. This will include improved missile warheads, kinetic energy penetrators, armors, and vehicle and munition systems. Products foreseen at this time include two generations of warheads, two generations of armors, one or two generations of kinetic energy penetrators, a vehicle survivability system, a wide area mine system, and an advanced combat vehicle testbed.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestones
--	Late FY 1987	Begin advanced development (AD) of Marine Corps light armor.

Project: #EE-21
Program Element: #63226E
USDR&E Mission Area: 530

Title: Armor/Anti-Armor Advanced Development
Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology

g. Explanation of Milestone Changes: This is a new project. No previous milestones were reported.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-23
Program Element: #63226E
USDR&E Mission Area: 530

Title: Enhanced Fighter Maneuverability (New Start)
Title: Experimental Evaluation of Major Innovation Technologies
Budget Activity: 1. Advanced Technology Development

H. PROJECTS OVER $7 MILLION IN FY 1988 - FY 1989:

1. Project Description: The Enhanced Fighter Maneuverability (EFM) program will integrate and demonstrate in flight a number of emerging technologies that collectively have the potential to significantly increase fighter aircraft agility and to improve close-in combat exchange ratios. The technical challenge is to produce a low-cost flight vehicle that will demonstrate the payoff of high agility at high angles of attack, using thrust vectoring, integrated flight and propulsion control systems, and configuration design. A dedicated flight demonstrator will produce data on the technical and military implications of post-stall maneuvering provided by EFM. Flight test will provide both research data for the relatively unexplored flight regime at high angles of attack, and will also provide a preliminary tactical assessment of post-stall maneuvers for close-in aerial combat. A low-cost approach to flight demonstrators will be used, and a data base for such proof-of-concepts flight vehicles will be generated for future application.

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: Phase One of the program, Concept Feasibility, was begun in FY 1985 and completed during FY 1986. This effort used extensive simulation data to show that close-in aerial combat could occur even for intentional Beyond Visual Range engagements, and that significant exchange ratio increases could result from using EFM technologies. This effort also investigated potential vehicles for flight demonstration and determined the need for a new dedicated EFM flight vehicle. Data from numerous unmanned simulations of up to 2-versus-4 engagements and manned 1-versus-1 simulations in Germany developed realistic assessments of post-stall maneuvering benefits. Phase Two, described below, was initiated in September 1986.

b. FY 1987 Program: Phase Two, Concept Validation and Design, will define a single baseline for the flight demonstrator, begin the design process, and validate the design concept by comparing this baseline with analytical and simulation results obtained in Phase One. Wind tunnel tests will be conducted to define stability and to provide design parameters for the control systems. Existing aircraft subsystems that may be used in the vehicle construction will be defined, and various cockpit designs and crew protection approaches will be investigated.

c. FY 1988 Planned Program and Basis for FY 1988 Request: During Phase Three, conducted over 18 months, the contractor will fabricate, assemble and ground test two Enhanced Fighter Maneuverability (EFM) flight demonstration vehicles. Low cost fabrication techniques will be used, including novel composite materials, as well as maximum practical use of Government Furnished Equipment. These novel fabrication and assembly techniques will be documented to serve as a data base for other programs.

d. FY 1989 Planned Program and Basis for FY 1989 Request: Ground testing, including vibration testing of the integrated flight and propulsion control systems, will be conducted during FY 1989. The first flight of the EFM demonstrator will occur in mid-FY 1989 and flight parameter identification data will be collected following the expansion

of the flight envelope. The second aircraft will be completed four months later, and it will follow a similar initial flight test program.

e. Program to Completion: Preliminary tactical evaluations of the high agility provided by the EFM demonstrator aircraft will be conducted during FY 1990. Measures of aircraft agility will lead to the conduct and evaluation of new tactical maneuvers. The payoff for aerial combat will be carefully evaluated in well controlled testing scenarios.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestones
N/A	Mid FY 1987	Preliminary Design Review
	Early FY 1988	Critical Design Review
	Mid FY 1989	Flight Readiness Review
	Mid FY 1989	First Flight

g. Explanation of Milestone Changes: Not Applicable

I. TEST AND EVALUATION DATA: Not Applicable.

J. COOPERATIVE AGREEMENTS: This program is being conducted with the Federal Republic of Germany under the Nunn-Quayle Research and Development Initiative. A Memorandum of Agreement (MOA) was signed in June 1986 between the United States Department of Defense and the German Federal Ministry of Defense (FMOD). The program description in the MOA cites the Enhanced Fighter Maneuverability (EFM) Phase One, Concept Feasibility, activities already completed during FY 1985-86, which established the feasibility and potential military payoffs of EFM maneuvering and tactics. Contractor activity for 12-month Phase Two, Concept Validation and Design, began in September 1986. Rockwell International Corporation (RI), with General Electric Corporation as a subcontractor, is the U.S. contractor and Messerschmitt-Bolkow-Blohm (MBB) is the German contractor. The funding profile for the U.S. contract with RI and the German contract with MBB is shown below. The two companies have signed an Associated Contract Agreement and have split the Phase Two effort into eight work packages, with MBB responsible for two packages and RI responsible for six packages, as well as for the entire EFM effort. The MOA also described Phase Three, the 18-month fabrication activity, and Phase Four, the 9-month flight test phase.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-23
Program Element: #63226E
USDR&E Mission Area: 530

Title: Enhanced Fighter Maneuverability (New Start)
Title: Experimental Evaluation of Major Innovation Technologies
Budget Activity: 1. Advanced Technology Development

($ in Thousands)

Funding Source	FY1986	FY1987	FY1988	FY1989
DARPA			15000	10000
Nunn-Quayle	8000	25000		
FMOD	500	3500	3000	3000

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Project: #EE-24
Program Element: #63226E
USDR&E Mission Area: 530

Title: ASTOVL
Title: Experimental Evaluation of Major Innovative Technologies
Budget Activity: 2. Advanced Technology Development

H. PROJECTS OVER $7 MILLION IN FY 1988 - 1989:

1. Project Description: The objective of this task is to develop a technology base in propulsion, aerodynamics, and integrated flight/propulsion controls. Fundamental development over a broad range of technologies is required to support the development of a high performance aircraft with vertical lift capability beyond the year 2000 A.D. The ability to incorporate short take off and vertical landing (STOVL) features in a highly maneuverable fighter aircraft is required to release land-based tactical aircraft from the operational vulnerability in easily targeted long runways. Current STOVL capability resides only in the subsonic attack aircraft, the AV-8B HARRIER. This technology base will resolve the issues associated with th incorporation of STOVL capability in a supersonic aircraft.

2. Program Accomplishments: Although this project is a new start in FY 1988, the technical base was established in FY 1986 and FY 1987 as an international research and development program in conjunction with the Nunn-Quayle Amendment and funded under Program Element 63790D. A brief summary of that work is included here for reference.

a. FY 1986 Accomplishments: In order to address critical path and high payoff efforts of the US/UK program, FY 1986 funds were applied to "quick start" technical efforts that directly supported the accomplishment of a joint DoD/MoD research program. One element of the critical path was the necessity for an integrated controls methodology development which could be exploited with the Vertical Systems Research Aircraft (VSRA), a modified AV-8B HARRIER. This aircraft was used to explore advanced flight control computers and software unique to supersonic aircraft. A second critical element, aeroacoustics technology, explores the fatigue caused by supersonic jets emanating from the different propulsion configurations that VTOL aircraft are subjected to. These two projects provided critical data that allowed a successful research plan to be negotiated with the UK Additional FY 1986 projects supported exploiting various propulsion techniques that apply to the propulsion requirements defined in the US/UK MOU on ASTOVL aircraft.

b. FY 1987 Program: The FY 1987 program (continued Nunn-Quayle funding) extended the VSRA and aeroacoustic work as well as an initiation of a joint effort with the Canadian firm, DiHavilland Company and US companies, General Dynamics and General Electric, to explore ejector technology as analternative propulsion method for vertical lift. These ejectors will be tested in a full-scale wind tunnel model, the E7, developed by General Dynamics. Since over twenty parameters must be controlled on an ASTOVL engine (nozzles settings, fuel flows, airflows, etc.) a major effort is required in engine control technology. In FY 1987, an initiative is scheduled to operate a full-scale engine under computer control while the response characteristics of the engine dynamics are related to the aerodynamic response times of a STOVL aircraft. A small effort is continuing in computational fluid dynamics to explore by computer the aerodynamics of various supersonic aircraft configurations.

c. FY 1988 Planned Program and Basis for FY 1988 Request: In FY 1988 the propulsion studies will be given to airframe contractors for use in conceptual designs of different ASTOVL configurations. The E7 propulsion system will be completed so that the ejector concept can be evaluated in a full-scale wind tunnel test. The majority of the computer

Project: #EE-24 Title: ASTOVL
Program Element: #63226E Title: Experimental Evaluation of Major Innovative Technologies
USDR&E Mission Area: 530 Budget Activity: 2. Advanced Technology Development

controlled propulsion testing will be performed on a ground-based NASA Lewis engine test stand. The computational fluid dynamics investigations will be completed. A small effort in thrust augmented nozzles will be completed. The majority of this data will be shared with both the Services and the United Kingdom (on an exchange basis).

d. FY 1989 Planned Program and Basis for FY 1989 Request: The majority of the FY 1989 effort will consist of the detailed design of a propulsion system for an ASTOVL demonstrator aircraft. This design will be justified from the ongoing (related) NASA airframe studies. The design will be sufficiently flexible to accommodate one or more propulsion concepts. The selection of the best propulsion concept will be made in conjunction with US/UK MOU guidelines and USAF interest. The integrated propulsion ground tests will be completed and the results used in the detailed engine design.

e. Program to Completion: Small scale studies in FY 1990 will complete this effort and support a national decision between DOD/NATO partners to embark on an ASTOVL prototype aircraft. FY 1990 will complete the technology base development effort.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestone
--	Late 1989	VSRA Flight Test
--	Mid 1989	Ejector Wind Tunnel Test
--	Early 1989	Engine Controls Demo
--	Late 1989	Complete Engine Studies

g. Explanation of Milestone Changes: Not applicable.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: The US/UK ASTOVL program MOU was signed January 1986 by NASA, DOD (USDRE), and the British MOD. It is the broad enabling document under which a joint international research and development program was established with FY 1986 and FY 1987 funding provided from the Nunn-Quayle Amendment (PE 63790D). All funding from FY 1988 through completion are provided by DARPA under this Program Element. Exchange of technical data is governed by that agreement as well as service release procedures that apply to particular work elements.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #63227E
USDR&E Mission Area: 530

Title: Strategic Relocatable Targets
Budget Activity: 2. Advanced Technology Development

A. RESOURCES: ($ in Thousands)

Project Number	Title	FY 1986 Actual	FY 1987 Estimate	FY 1988 Estimate	FY 1989 Estimate	Additional to Completion	Total Estimated Costs
	Strategic Relocatable Targets	0	0	6,700	17,400	Continuing	N/A

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED:

This program element is dedicated to advanced experimentation and analysis to develop means of detecting and identifying mobile Inter-Continental Ballistic Missiles (ICBM) and other strategic relocatable targets. The capability to hold these mobile ICBM's and Intermediate Range Ballistic Missiles (IRBMs) at risk requires successful execution of search, detection and identification processes; communication, command and control processes to direct weapons at these targets; and weapon delivery and kill.

C. COMPARISON WITH FY 1987 DESCRIPTIVE SUMMARY: Not applicable - this is a new start.

D. OTHER APPROPRIATION FUNDS: None.

E. RELATED ACTIVITIES: Overall coordination of efforts is maintained with representatives of the Office of the Under Secretary of Defense (Acquisition), Deputy Under Secretary for Strategic and Tactical Nuclear Systems, the Air Force Assistant Secretary for Research and Development, the Central Intelligence Agency and Defense Intelligence Agency, the Air Force Headquarters Research and Development staff and the Strategic Air Command. This program is overseen directly by a Department of Defense Steering Committee consisting of representatives from the Army, Air Force, Intelligence Community, Joint Chiefs of Staff, Office of the Secretary of Defense, and Defense Advanced Research Projects Agency. In addition, direct coordination with appropriate Service laboratories is maintained through meetings and conferences. These include the Air Force Rome Air Development Center, Air Force Aeronautical Systems Division and others as appropriate.

F. WORK PERFORMED BY: Massachusetts Institute of Technology/Lincoln Laboratories, Lexington, MA; and Environmental Research Institute of Michigan (ERIM), Ann Arbor, MI.

G. PROJECTS LESS THAN $7 MILLION IN FY 1988: Not applicable.

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: The Strategic Relocatable Targets (SRT) Program was initiated by the DoD Relocatable Target

Program Element: #63227E
USDR&E Mission Area: 530

Title: Strategic Relocatable Targets
Budget Activity: 2. Advanced Technology Development

Master Planning Group. It is designed to investigate technologies for detection and identification of mobile Inter-Continental Ballistic Missiles (ICBMs). The program includes experimentation and analysis and puts a strong emphasis on building a scientific base in detection and identification signatures, sensors and processing. The experimental effort will characterize target signature and target contrast. The accompanying analytic effort will develop robust detection and identification algorithms. Sensor systems to be developed and used in the experiments include microwave radar (Synthetic Aperture Radar (SAR) and Moving Target Indicator (MTI)), infrared (IR), electro-optical (EO), laser radar, Signal Intelligence (SIGINT), acoustic, and perhaps low-frequency foliage penetration radar. Analytic techniques to be evaluated and developed include conventional signal processing (matched filtering techniques), machine intelligence applications, and self-learning techniques. A parallel operational effectiveness analysis will also be conducted to develop analytical models to assess alternative system architectures.

The Strategic Relocatable Targets (SRT) Program will capitalize on the research efforts achieved in other programs. Examples of programs include: The Tactical Use of National Technical Means (TACNAT), Autonomous Infrared Sensor Technology (AIRSTECH), Millimeter Wave (MMW) Autonomous Sensor, Advanced Digital Radar Imagery Exploitation (ADRIES), and Smart Weapons. (See program element 62702E and 62301E for descriptions of these programs.)

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: The Strategic Relocatable Targets Program is a new one for FY 1988 and as such has no accomplishments. However, it will build on the accomplishments of the programs listed above. An example is the technology developed in the TACNAT Program which yields dramatic reductions in area search.

b. FY 1987 Program: The Defense Advanced Research Projects Agency component of the Strategic Relocatable Targets Program will not start until FY 1988.

c. FY 1988 Planned Program and Basis for FY 1988 Request: Operational effectiveness analyses, systems analyses and analyses of existing data, simulators and sensors will be initiated. Typical systems analyses include: characterization of land cover in the deployment area, sensor systems architectures and tradeoffs, and analyses of deployment tactics. Acquisition of and access to experimental hardware will begin. This will include: synthetic aperture radar (SAR) infrared (IR)/electro-optical (EO)/laser sensors, signals intelligence (SIGINT) sensors, moving target indicator (MTI) sensor, and acoustic/seismic sensors. Some existing sensors will have to be upgraded to support the calibration and recording required for the rigorous scientific experiments that are planned.

d. FY 1989 Planned Program and Basis for FY 1989 Request: Experiment execution, data analysis and algorithm development will begin for the SAR radar, IR/EO/laser, SIGINT and acoustic/seismic sensors. Various instruments and sensors will be calibrated, experiments conducted, data reduced and analyzed, and techniques and algorithms for strategic target location and identification developed.

Program Element: #63227E
USDR&E Mission Area: 530
Development

Title: Stracegic Relocatable Targets
Budget Activity: 2. Advanced Technology

e. Program to Completion: Experiments with moving target indicator (MTI) radar will be conducted. Experimentation, data analysis and technique development for the other sensors will continue. Interaction with and dissemination of Strategic Relocatable Targets research results to the large community concerned with strategic relocatable targets will go on throughout the life of the Program.

f. Milestones:

Last Year's Reported Plan	Current Plan	Milestones
--	Early FY 1988	Systems and operational effectiveness analyses will begin.
--		Analyses of existing data and sensors completed.
--		Enhanced sensors available.
--		MTI radar developed.
--		Initial synthetic aperture radar (SAR) data analyses and algorithms completed.
--		Initial infrared (IR)/electro-optical (EO)/laser, signal intelligence (SIGINT), acoustic/seismic data analyses and algorithms completed.

g. Explanation of Milestone Changes: Not applicable.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: 65872E
USDR&E Mission Area: 530

Title: Productivity Investment Funding
Budget Activity: 6. Defensewide Mission Support

A. RESOURCES: ($ in Thousands)

Project Number	Title	FY 1986 Actual	FY 1987 Estimate	FY 1988 Estimate	FY 1989 Estimate	Additional to Completion	Total Estimated Cost
TOTAL FOR PROGRAM ELEMENT		--	--	$2,000	$1,000	--	$3,000
PIP-01	Artificial Intelligence System	--	--	$2,000	--	--	$2,000
PIP-02	Accelerated Acquisition Automation	--	--	--	$1,000	--	$1,000

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This program element is part of the DoD-wide Productivity Investment Funding which sets aside resources for productivity enhancing projects. Funding is selectively awarded to offices throughout DoD based on expected economic benefits and overall contributions to Defense readiness. The projects of this program element are specifically planned to increase the productivity of DARPA program managers and the various support personnel responsible for the timely commitment and obligation of funds in the DARPA RDT&E acquisition process.

C. COMPARISON WITH FY 1987 DESCRIPTIVE SUMMARY: Not Applicable. This is a new program element.

D. OTHER APPROPRIATION FUNDS: All funding is through the Defense Productivity Program Office of the Defense Logistics Agency, OASD (Force Management and Personnel).

E. RELATED ACTIVITIES: This effort is a part of, and coordinated by, the Defense Productivity Program Office to ensure careful prioritization and non-duplication within the Department of Defense.

F. WORK PERFORMED BY: It is anticipated that the work will be 100% performed by industry on a competitively selected basis.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: 65872E
USDR&E Mission Area: 530

Title: Productivity Investment Funding
Budget Activity: 6. Defensewide Mission Support

G. PROJECTS LESS THAN $7 MILLION IN FY 1988-1989: Project No. PIF-01 will be entirely funded in FY 1988 and will develop and implement an expert system to reduce the administrative effort of technical program managers in the preparation of original documentation of research and development acquisition packages. Project No. PIF-02 will be entirely funded in FY 1989 and will acquire commercially available hardware and software, and develop additional software: to (1) automate the preparation, review and internal management of acquisition packages; and (2) establish electronic linkages with various DARPA agents within the Defense RDT&E community to avoid processing delays and burdensome tracking/monitoring efforts now being experienced.

H. PROJECTS OVER $7 MILLION IN FY 1988: Not Applicable.

I. TEST AND EVALUATION DATA: Not Applicable.

J. COOPERATIVE AGREEMENTS: Not Applicable.

FY 1988-1989 RDT&E DESCRIPTIVE SUMMARY

Program Element: #65898E
USDR&E Mission Area: 474

Title: Management Headquarters (R&D)
Budget Activity: 6. Defensewide Mission Support

A. RESOURCES: ($ in Thousands)

Project Number	Title	FY 1986 Actual	FY 1987 Estimate	FY 1988 Estimate	FY 1989 Estimate	Additional To Completion	Total Estimated Cost
	TOTAL FOR PROGRAM ELEMENT	12,192	12,298	14,558	15,410	Continuing	N/A

B. BRIEF DESCRIPTION OF ELEMENT AND MISSION NEED: This program element provides funds for payment of salaries to civilian employees and for administrative support costs of the Defense Advanced Research Projects Agency (DARPA). This funding provides for the personnel compensation and benefits for civilians assigned to DARPA as well as costs for building rent and security, travel, supplies and equipment, communications, printing and reproduction. In addition, funds are included for reimbursing the Military Services for administrative support costs associated with contracts undertaken on the Agency's behalf.

C. COMPARISON WITH FY 1987 DESCRIPTIVE SUMMARY: The FY 1988 funding increase reflects the January 1987 pay raise for federal employees and the addition of fourteen billets to establish an expanded prototype role for DARPA in joint programs and other areas not adequately addressed by the Services, and to establish a limited contracting authority for awarding definition contracts.

D. OTHER APPROPRIATION FUNDS: None.

E. RELATED ACTIVITIES: Not applicable.

F. WORK PERFORMED BY: Civilian and military personnel assigned to the Defense Advanced Research Projects Agency and by DARPA agent personnel operating within the Military Services.

G. PROJECTS LESS THAN $7 MILLION IN FY 1988-1989: Not applicable.

H. PROJECTS OVER $7 MILLION IN FY 1988-1989:

1. Project Description: This project provides funds for normal management and support functions of the Defense Advanced Research Projects Agency (DARPA). The funding includes civilian personnel compensation and benefits, and costs for travel, building rent and security, supplies and equipment, communications, printing and reproduction. Funding is included for the reimbursement of administrative support costs associated with contracts undertaken on DARPA's behalf by the Military Services.

Program Element: #65898E
USDR&E Mission Area: 474

Title: Management Headquarters (R&D)
Budget Activity: 6. Defensewide Mission Support

2. Program Accomplishments and Future Programs:

a. FY 1986 Accomplishments: Funding under this program element in FY 1986 supported management and administration for the RDT&E program assigned to DARPA. The majority of the funds were required for the pay of personnel who operate the Agency. Beginning in FY 1983, this project included funding to reimburse the various Service agents for costs associated with their administration of DARPA's contracts. These funds had been previously budgeted in the technical program elements which had funded the technology base programs.

b. FY 1987 Program: Continuation of the management and administrative support costs for DARPA is planned.

c. FY 1988 Planned Program and Basis for FY 1988 Request: The management and administrative support costs for headquarters DARPA will continue at approximately the same level as FY 1987. The major increases are in physical and information security improvements and personnel compensation and benefits for the fourteen additional billets associated with DARPA's expanded prototyping role and limited contracting capability.

d. FY 1989 Planned Program and Basis for FY 1989 Request: The management and administrative support costs for headquarters DARPA will continue at approximately the same level as in FY 1988.

e. Program to Completion: This is a continuing program.

f. Milestones: Not applicable.

g. Explanation of Milestone Changes: Not applicable.

I. TEST AND EVALUATION DATA: Not applicable.

J. COOPERATIVE AGREEMENTS: Not applicable.